PATENT ABSTRACTS OF JAPAN

(51)Int.Cl.	H01Q 3/44
	H01Q 3/26
	H01Q 9/32
	H01Q 9/38
	H01Q 19/32
	H01Q 21/20

(54) CONTROLLER AND CONTROLLING METHOD OF ARRAY ANTENNA

(57)Abstract:

PROBLEM TO BE SOLVED: To perform adaptive control of an ESPAR antenna such that a main beam is directed toward a desired wave and null is directed toward an interference wave with no need for imparting the incoming angle of receiving signal previously.

SOLUTION: The controller 40 performing adaptive control of an array antenna unit 100 of ESPAR antenna comprising one feed antenna element A0 and six parasitic variable reactance elements A1-A6 executes adaptive control shown on Fig. 8 based on a receiving signal y(t) at the time when a learning sequence signal included in a radio signal transmitted from the opposite transmitter is received by the feed antenna element A0 of the array antenna unit 100, and a learning sequence signal r(t) generated from a learning sequence signal generator 41 and identical to the learning sequence signal to calculate and set the reactance value xm of each variable reactance element A1-A6 for directing the main beam of the array antenna unit 100 in the direction of desired wave and directing null in the direction of interference wave.
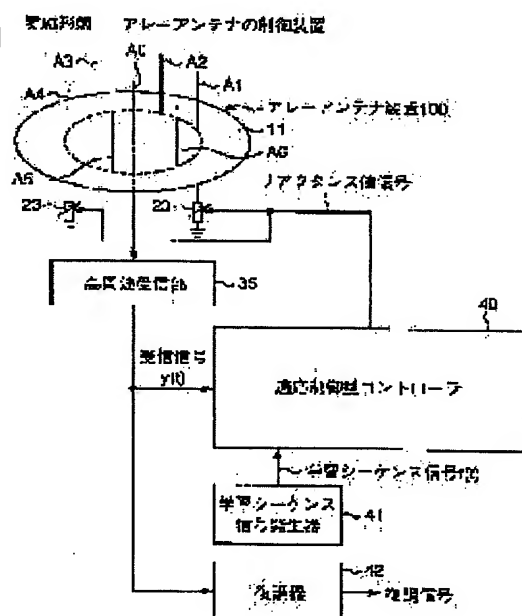
LEGAL STATUS

[Date of request for examination] 12.03.2001

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]   3669915
[Date of registration]   22.04.2005
[Number of appeal against examiner's decision
of rejection]
[Date of requesting appeal against examiner's
decision of rejection]
[Date of extinction of right]

(19)日本国特許庁（JP） (12) **公 開 特 許 公 報**（A） (11)特許出願公開番号

特開2002−118414

（P2002−118414A）

(43)公開日 平成14年4月19日（2002.4.19）

(51)Int.Cl.⁷	識別記号		FI		テーマコード（参考）
H01Q	3/44		H01Q	3/44	5J020
	3/26			3/26	Z 5J021
	9/32			9/32	
	9/38			9/38	
	19/32			19/32	

審査請求 有 請求項の数5 OL （全16頁） 最終頁に続く

|			
(21)出願番号	特願2000−307548（P2000−307548）	(71)出願人	396011680
			株式会社エイ・ティ・アール環境適応通信
			研究所
(22)出願日	平成12年10月6日（2000.10.6）		京都府相楽郡精華町光台二丁目2番地2
		(72)発明者	程 俊
			京都府相楽郡精華町光台二丁目2番地2
			株式会社エイ・ティ・アール環境適応通信
			研究所内
		(74)代理人	100062144
			弁理士 青山 葆 （外2名）

最終頁に続く

(54)【発明の名称】 アレーアンテナの制御装置及び制御方法

(57)【要約】

【課題】 エスパアンテナの制御において、受信信号の到来角度を予め与える必要がなく、所望波に主ビームを向けかつ干渉波にヌルを向けるように適応制御する。

【解決手段】 1つの給電アンテナ素子A0と、6個の無給電可変リアクタンス素子A1乃至A6を備えてなるエスパアンテナのアレーアンテナ装置100を適応制御するための適応制御型コントローラ40は、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号をアレーアンテナ装置100の給電アンテナ素子A0により受信したときの受信信号y（t）と、学習シーケンス信号と同一であり学習シーケンス信号発生器41で発生された学習シーケンス信号r（t）とに基づいて、図8の適応制御処理を実行してアレーアンテナ装置100の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子A1乃至A6のリアクタンス値xₙを計算して設定する。

実施形態 アレーアンテナの制御装置

1
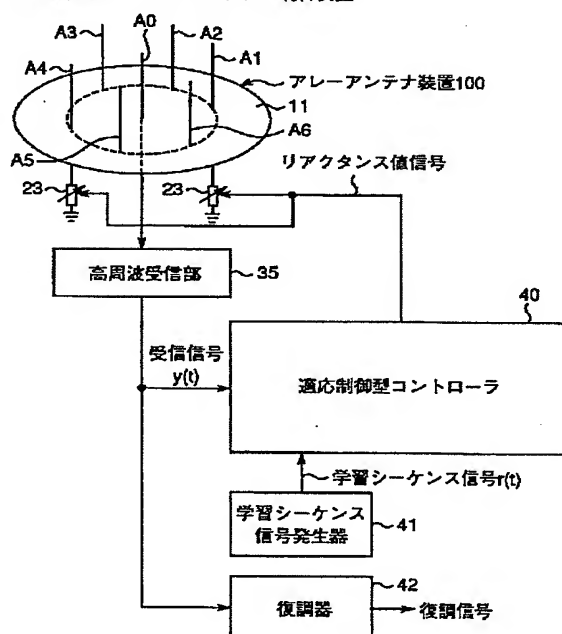
【特許請求の範囲】

【請求項１】　無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御装置において、上記各可変リアクタンス素子のリアクタンス値を順次所定のシフト量だけ摂動させ、各リアクタンス値に対する所定の評価関数値の傾斜ベクトルを計算し、計算された傾斜ベクトルに基づいて当該評価関数値が最大又は最小となるように、上記アレーアンテナの主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子のリアクタンス値を計算して設定する制御手段を備えたことを特徴とするアレーアンテナの制御装置。

【請求項２】　上記制御手段は、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号を上記アレーアンテナにより受信したときの受信信号と、上記学習シーケンス信号と同一であり当該制御手段で発生された学習シーケンス信号とに基づいて上記評価関数値を計算し、当該評価関数値が最大となるように制御し、上記評価関数は、上記受信信号と上記発生された学習シーケンス信号との間の相互相関係数であることを特徴とする請求項１記載のアレーアンテナの制御装置。

【請求項３】　上記制御手段は、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号を上記アレーアンテナにより受信したときの受信信号と、上記学習シーケンス信号と同一であり当該制御手段で発生された学習シーケンス信号とに基づいて上記評価関数値を計算し、当該評価関数値が最小となるように制御し、上記評価関数は、上記受信信号と上記発生された学習シーケンス信号との間の二乗誤差であることを特徴とする請求項１記載のアレーアンテナの制御装置。

【請求項４】　上記制御手段は、相手先の送信機から送信される無線信号を上記アレーアンテナにより受信したときの受信信号に基づいて上記評価関数値を計算し、当該評価関数値が最小となるように制御し、上記評価関数は、上記受信信号の包絡線が一定値となるときに最小となる関数であることを特徴とする請求項１記載のアレーアンテナの制御装置。

【請求項５】　無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、

2

上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御方法において、上記各可変リアクタンス素子のリアクタンス値を順次所定のシフト量だけ摂動させ、各リアクタンス値に対する所定の評価関数値の傾斜ベクトルを計算し、計算された傾斜ベクトルに基づいて当該評価関数値が最大又は最小となるように、上記アレーアンテナの主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子のリアクタンス値を計算して設定するステップを含むことを特徴とするアレーアンテナの制御方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、複数のアンテナ素子からなるアレーアンテナ装置の指向特性を変化させることができるアレーアンテナの制御装置及び制御方法に関し、特に、電子制御導波器アレーアンテナ装置（Electronically Steerable Passive Array Radiator (ESPAR) Antenna；以下、エスパアンテナという。）指向特性を適応的に変化させることができるアレーアンテナの制御装置及び制御方法に関する。

【０００２】

【従来の技術】従来技術のエスパアンテナは、例えば、従来技術文献１「T. Ohira et al., "Electronically steerable passive array radiator antennas for low-cost analog adaptive beamforming," 2000 IEEE International Conference on PhasedArray System & Technology pp. 101-104, Dana point, California, May 21-25, 2000」や特願平１１－１９４４８７号の特許出願において提案されている。このエスパアンテナは、無線信号が給電される放射素子と、この放射素子から所定の間隔だけ離れて設けられ、無線信号が給電されない少なくとも１個の非励振素子と、この非励振素子に接続された可変リアクタンス素子とから成るアレーアンテナを備え、上記可変リアクタンス素子のリアクタンス値を変化させることにより、上記アレーアンテナの指向特性を変化させることができる。

【０００３】上記のエスパアンテナを制御するための方法として、例えば、特願２０００－１９８５６０号の特許出願において、各可変リアクタンス素子のリアクタンス値を最適化するために、ハミルトニアン法を用いて、指定した方位角のアンテナ利得を最大にするようなリアクタンス値を計算している。

【０００４】

【発明が解決しようとする課題】しかしながら、この従来例では、受信信号の到来角度を予め与える必要があり、実用的ではなく、また、干渉波に対してヌルを向け

3

ることができないという問題点があった。

【０００５】本発明の目的は以上の問題点を解決し、エスパアンテナの制御において、受信信号の到来角度を予め与える必要がなく、所望波に対して主ビームを向けかつ干渉波に対してヌルを向けるように適応制御することができるアレーアンテナの制御装置及び制御方法を提供することにある。

【０００６】
【課題を解決するための手段】本発明に係るアレーアンテナの制御装置は、無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御装置において、上記各可変リアクタンス素子のリアクタンス値を順次所定のシフト量だけ摂動させ、各リアクタンス値に対する所定の評価関数値の傾斜ベクトルを計算し、計算された傾斜ベクトルに基づいて当該評価関数値が最大又は最小となるように、上記アレーアンテナの主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子のリアクタンス値を計算して設定する制御手段を備えたことを特徴とする。

【０００７】また、上記アレーアンテナの制御装置において、上記制御手段は、好ましくは、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号を上記アレーアンテナにより受信したときの受信信号と、上記学習シーケンス信号と同一であり当該制御手段で発生された学習シーケンス信号とに基づいて上記評価関数値を計算し、当該評価関数値が最大となるように制御し、上記評価関数は、上記受信信号と上記発生された学習シーケンス信号との間の相互相関係数であることを特徴とする。

【０００８】さらに、上記アレーアンテナの制御装置において、上記制御手段は、好ましくは、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号を上記アレーアンテナにより受信したときの受信信号と、上記学習シーケンス信号と同一であり当該制御手段で発生された学習シーケンス信号とに基づいて上記評価関数値を計算し、当該評価関数値が最小となるように制御し、上記評価関数は、上記受信信号と上記発生された学習シーケンス信号との間の二乗誤差であることを特徴とする。

【０００９】またさらに、上記アレーアンテナの制御装置において、上記制御手段は、好ましくは、相手先の送信機から送信される無線信号を上記アレーアンテナにより受信したときの受信信号に基づいて上記評価関数値を計算し、当該評価関数値が最小となるように制御し、上

4

記評価関数は、上記受信信号の包絡線が一定値となるときに最小となる関数であることを特徴とする。

【００１０】また、本発明に係るアレーアンテナの制御方法は、無線信号を受信するための放射素子と、上記放射素子から所定の間隔だけ離れて設けられた複数の非励振素子と、上記複数の非励振素子にそれぞれ接続された複数の可変リアクタンス素子とを備え、上記各可変リアクタンス素子のリアクタンス値を変化させることにより、上記複数の可変リアクタンス素子をそれぞれ導波器又は反射器として動作させ、アレーアンテナの指向特性を変化させるアレーアンテナの制御方法において、上記各可変リアクタンス素子のリアクタンス値を順次所定のシフト量だけ摂動させ、各リアクタンス値に対する所定の評価関数値の傾斜ベクトルを計算し、計算された傾斜ベクトルに基づいて当該評価関数値が最大又は最小となるように、上記アレーアンテナの主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子のリアクタンス値を計算して設定するステップを含むことを特徴とする。

【００１１】
【発明の実施の形態】以下、図面を参照して本発明に係る実施形態について説明する。

【００１２】図１は本発明に係る実施形態であるアレーアンテナの制御装置の構成を示すブロック図である。この実施形態のアレーアンテナの制御装置は、図１に示すように、１つの給電アンテナ素子Ａ０と、６個の無給電可変リアクタンス素子Ａ１乃至Ａ６とを備えてなる従来技術のエスパアンテナで構成されたアレーアンテナ装置１００と、適応制御型コントローラ４０と、学習シーケンス信号発生器４１とを備える。

【００１３】ここで、適応制御型コントローラ４０は、例えばコンピュータなどのディジタル計算機で構成され、復調器４２による無線通信を開始する前に、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号を上記アレーアンテナ装置１００の給電アンテナ素子Ａ０により受信したときの受信信号 $y(t)$ と、上記学習シーケンス信号と同一であり学習シーケンス信号発生器４１で発生された学習シーケンス信号 $r(t)$ とに基づいて、図８の適応制御処理を実行することにより上記アレーアンテナ装置１００の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子Ａ１乃至Ａ６のリアクタンス値 x_m $(m=1, 2, \cdots, 6)$ を計算して設定することを特徴としている。具体的には、適応制御型コントローラ４０は、各可変リアクタンス素子Ａ１乃至Ａ６のリアクタンス値 x_m $(m=1, 2, \cdots, 6)$ を順次所定のシフト量 Δx_m だけ摂動させ、各リアクタンス値に対する所定の評価関数（本実施形態では、数２３で表される、受信信号 $y(t)$ と上記発生された学習シーケンス信号 $r(t)$ との間の相互相関係数 ρ_n）の値の傾斜ベクトル

5

を計算し、計算された傾斜ベクトルに基づいて当該評価関数値が最大となるように、上記アレーアンテナ装置１００の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子Ａ１乃至Ａ６のリアクタンス値ｘ．（ｍ＝１，２，…，６）を計算して設定する。

【００１４】図１において、相手先の送信機から送信された無線信号は、アレーアンテナ装置１００で受信され、その給電アンテナ素子Ａ０から出力される信号は、低雑音増幅、中間周波又はバースバンドへの周波数変換などの処理を行う高周波受信部３５を介して、受信信号ｙ（ｔ）として適応制御型コントローラ４０及び復調器４２に伝送される。上記適応制御型コントローラ４０は、上述の適応制御処理を実行してアレーアンテナの制御装置１００の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるように適応制御した後、復調器４２による無線通信が開始される。ここで、復調器４２は、受信された受信信号ｙ（ｔ）に対して、復調などの処理を実行して復調信号を得て出力する。

【００１５】まず、図２乃至図５を参照してエスパアンテナで構成されたアレーアンテナ装置１００の構成について説明する。アレーアンテナ装置１００においては、図２に示すように、給電アンテナ素子Ａ０と、６本の無給電可変リアクタンス素子Ａ１乃至Ａ６とがそれぞれ、各無給電可変リアクタンス素子Ａ０乃至Ａ６の長さ１ｏ，１ｍ（ｍ＝１，２，…，６）に対して十分に大きい広さを有する導体板にてなる接地導体１１から電気的に絶縁され、かつ給電アンテナ素子Ａ０を中心とする例えば半径ｄ＝λ／４（但しλは波長）の円形形状の位置に互いに同一の６０度の間隔で無給電可変リアクタンス素子Ａ１乃至Ａ６が配置されるように設けられる。ここで、アレーアンテナ装置１００は、可逆回路であって、送信アンテナとして用いるときは、給電アンテナ素子Ａ０のみに無線信号が給電される一方、受信アンテナとして用いるときは、相手先の送信機からの無線信号が給電アンテナ素子Ａ０により受信信号ｙ（ｔ）として受信される。

【００１６】図３において、給電アンテナ素子Ａ０は、例えばλ／４の所定の長手方向の長さ１ｏを有し接地導体１１とは電気的に絶縁された円柱形状の放射素子６を備え、放射素子６により受信された無線信号を伝送する同軸ケーブル２０の中心導体２１は放射素子６の一端に接続され、その外部導体２２は接地導体１１に接続される。これにより、放射素子６により受信された無線信号を同軸ケーブル２０を介して、さらには高周波受信部３５を介して適応制御型コントローラ４０及び復調器４２に伝送する。

【００１７】図４において、各無給電可変リアクタンス素子Ａ１乃至Ａ６はそれぞれ、例えばλ／４の所定の長手方向の長さ１ｍ（ｍ＝１，２，…，６）を有し接地導

6

体１１とは電気的に絶縁された円柱形状の非励振素子７と、リアクタンス値ｘ．（ｍ＝１，２，…，６）を有する可変リアクタンス素子２３とを備えて同様の構造を有して構成される。ここで、非励振素子７の一端は可変リアクタンス素子２３を介して接地導体１１に対して高周波的に接地される。例えば放射素子６と非励振素子７の長手方向の長さが実質的に同一であると仮定したとき、例えば、可変リアクタンス素子２３がインダクタンス性（Ｌ性）を有するときは、可変リアクタンス素子２３は延長コイルとなり、無給電可変リアクタンス素子Ａ１乃至Ａ６の電気長が給電アンテナ素子Ａ０に比較して長くなり、反射器として働く。一方、例えば、可変リアクタンス素子２３がキャパシタンス性（Ｃ性）を有するときは、可変リアクタンス素子２３は短縮コンデンサとなり、無給電可変リアクタンス素子Ａ１乃至Ａ６の電気長が給電アンテナ素子Ａ０に比較して短くなり、導波器として働く。実際の適用では、リアクタンスｘ．は、－３００Ωから３００Ωまで等の一定範囲に制約することができる。

【００１８】図５は、図１のアレーアンテナ装置１００の詳細な構成を示す断面図であり、図５の好ましい実施形態では、可変リアクタンス素子２３として可変容量ダイオードＤを用いている。

【００１９】図５において、例えばポリカーボネートなどの誘電体基板１０の上面に接地導体１１が形成され、放射素子６は、接地導体１１から電気的に絶縁されつつ、誘電体基板１０を厚さ方向に貫通して支持されている。また、非励振素子７は接地導体１１から電気的に絶縁されつつ、誘電体基板１０を厚さ方向に貫通して支持される。ここで、非励振素子７の一端は可変容量ダイオードＤ及び、誘電体基板１０を厚さ方向に貫通して充填形成されてなるスルーホール導体１２を介して接地導体１１に高周波的に接地されるとともに、抵抗Ｒを介して端子Ｔに接続される。また、端子Ｔは高周波バイパス用キャパシタＣ及び、誘電体基板１０を厚さ方向に貫通して充填形成されてなるスルーホール導体１３を介して接地導体１１に高周波的に接地される。

【００２０】端子Ｔには、適応制御型コントローラ４０により電圧制御される可変電圧直流電源３０が接続され、これにより、可変容量ダイオードＤに印加する逆バイアス電圧を変化させることにより、可変容量ダイオードＤにおける静電容量値を変化させる。これにより、非励振素子７を備えた無給電可変リアクタンス素子Ａ１の電気長を、給電アンテナ素子Ａ０に比較して変化させ、当該アレーアンテナ装置１００の平面指向性特性を変化させることができる。さらに、他の非励振素子７を備えた無給電可変リアクタンス素子Ａ２乃至Ａ６も同様に構成されて同様の作用を有する。

【００２１】以上のように構成されたアレーアンテナ装置１００は、エスパアンテナと呼ばれる。本実施形態で

　　　　　　　　　７

はさらに、図１のアレーアンテナ装置１００において、各無給電可変リアクタンス素子Ａ１乃至Ａ６に接続された可変リアクタンス素子２３のリアクタンス値を変化させることにより、アレーアンテナ装置１００の全体の平面指向性特性を適応的に制御するための制御装置及び制御方法を提供する。

【００２２】エスパアンテナで構成されたアレーアンテナ装置１００のための適応制御型コントローラ４０からの出力信号であるリアクタンス値信号を、これらの６個のリアクタンスの関数として簡単に定式化する。本実施形態では、各可変リアクタンス素子２３のリアクタンス値を成分として持つ、

【数１】$x \equiv [x_1, x_2, \cdots, x_6]^T$

で表されるベクトルをリアクタンスベクトルと呼び、上記リアクタンスベクトルは可変であるので、アレーアンテナ装置１００の指向性パターンの形成に使用する。

【００２３】本実施形態において、信号ベクトルｓ（ｔ）を、

【数２】
$s(t) = [s_0(t), s_1(t), \cdots, s_6(t)]^T$

で定義し、成分$s_m(t)$は、アレーアンテナ装置１００のｍ番目（ｍ＝０，１，…，６）のアンテナ素子Ａｍ（すなわち給電アンテナ素子又は無給電リアクタンス素子）で受信されるＲＦ信号であり、上付き文字Ｔはベクトル又は行列の転置を表す。次に、アレーアンテナ装置１００の単一ポートのＲＦ出力信号である受信信号ｙ（ｔ）（以下の原理説明では、説明の便宜上、高周波受信部３５の前段での高周波信号（ＲＦ信号）をいう。）は次式によって与えられる。

【数３】$y(t) = i^T s(t)$

ここで、

【数４】$i = [i_0, i_1, i_2, \cdots, i_6]^T$

はｍ番目のアンテナ素子Ａｍ上に現れるＲＦ電流を成分i_mとして持つベクトルである。

【００２４】アレーアンテナ装置１００の電磁界解析によれば、ＲＦ電流ベクトルｉは次式のように定式化される。

【数５】$i = (I + jYX)^{-1} y_0$

【００２５】ここで、Ｉは（６＋１）×（６＋１）の単位行列であり、対角行列

【数６】$X = \mathrm{diag}[x_0, x_1, x_2, \cdots, x_6]$

は、リアクタンス行列と呼ばれる。適応制御型コントローラ４０及び復調器４２の入力インピーダンスx_0は一定であり、本実施形態では、一般性を失うことなくx_0＝０と仮定している。さらに、数５では、ベクトルy_0は、

【数７】$y_0 = [y_{00}, y_{10}, y_{20}, \cdots, y_{60}]^T$

で定義し、また、

【数８】$Y = [y_{kl}]_{(6+1) \times (6+1)}$

は（６＋１）×（６＋１）のアドミタンス行列であるも

　　　　　　　　　８

のとする。ここで、成分y_{kl}はアンテナ素子ＡｋとＡｌとの間（$0 \leqq k, l \leqq 6$）の相互アドミタンスを表す。

【００２６】（６＋１）素子のアレーアンテナ装置１００の場合、ベクトルy_0及びアドミタンス行列Ｙは、相互アドミタンスの６個の成分のみで決定される。これについて以下に説明する。

【００２７】公知の相反定理により、通常型のアレーアンテナ装置と同様に次式が成り立つ。

【数９】$y_{kl} = y_{lk}$

【００２８】さらに、アレーアンテナ装置１００のアンテナ素子Ａｍの巡回対称性は次式を含意している。

【００２９】

【数１０】$y_{11} = y_{22} = y_{33} = y_{44} = y_{55} = y_{66}$

【数１１】$y_{01} = y_{02} = y_{03} = y_{04} = y_{05} = y_{06}$

【数１２】$y_{12} = y_{23} = y_{34} = y_{45} = y_{56} = y_{61}$

【数１３】$y_{13} = y_{24} = y_{35} = y_{46} = y_{51} = y_{62}$

【数１４】$y_{14} = y_{25} = y_{36}$

【００３０】上記数９乃至数１４は、数８のアドミタンス行列が相互アドミタンスの６個の成分y_{00}、y_{10}、y_{11}、y_{21}、y_{31}及びy_{41}のみによって決定されることを意味している。６つの成分の値は、アンテナ素子Ａｍの半径、空間間隔及び長さ等のアンテナの物理的構造に依存し、よってこれは一定である。これまでの説明を要約して、数５におけるアドミタンス行列Ｙを次式のように表記する。

【００３１】

【数１５】

$$Y = \begin{bmatrix} y_{00} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} \\ y_{10} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} \\ y_{10} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} \\ y_{10} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} \\ y_{10} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} \\ y_{10} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} \\ y_{10} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} \end{bmatrix}$$

【００３２】同様に、数７は次のように書き換えることができる。

【数１６】$Y = [y_{00}, y_{10}, y_{10}, \cdots, y_{10}]^T$

【００３３】アレーアンテナ装置１００のアンテナ素子で受信される数３における信号ベクトルｓ（ｔ）は測定不能であることは強調すべき点である。これは、アンテナ素子上で受信される信号ベクトルが観測される通常の適応型アレーアンテナとは異なる。アレーアンテナ装置１００の場合は、単一ポート出力である受信信号ｙ（ｔ）のみが測定可能であり、これだけが数１のリアクタンスベクトルｘを制御するフィードバックとして使用される。さらに残念ながら、数５が示すように、単一ポート出力である受信信号ｙ（ｔ）はリアクタンスベクトルｘの高次の非線形関数であって、逆行列の演算を含んでおり、これが適応性能の解析的表現の生成を困難にしている。また、数５における電流ベクトルｉは通常の適

9

応型アレーの重み係数ベクトルに相当することも注意されるべきである。電流ベクトル ｉ の各成分は、通常の適応型アレーの重み係数ベクトルとは違って独立ではなく互いに結合していることは数5から明らかである。上述の議論は、通常の適応型アレーアンテナの制御アルゴリズムの大部分は、エスバアンテナの技術を適用されたアレーアンテナ装置１００に直接に適用することが不可能であることを含意している。従って、特に、エスバアンテナのための適応制御用アルゴリズムを提案することが望ましい。

【００３４】次いで、本実施形態のアレーアンテナ装置１００を適応型にするために、受信される信号のモデルを提案する。論考を進める前に、アレーアンテナ装置１００の操向ベクトルを与えておく。図6に示されるような（6＋1）素子のアレーアンテナ装置１００について考察する。

【００３５】ｍ番目のアンテナ素子Ａｍを、任意の軸に対して角度

【数１７】

$$\phi_m = 2\pi(m-1)/6, \quad (m=1, 2, \cdots, 6)$$

で配置する。図6ではｍ＝2の場合が図示されている。上記任意の軸を基準軸として角度 θ の到来角度（ＤＯＡ）から到来し、アレーアンテナ装置１００上で受信される波面が観測されるとき、ｍ番目の無給電リアクタンス素子Ａｍと0番目の給電アンテナ素子Ａ0の対が受信する信号間には $d \cdot \cos(\theta - \phi_m)$ の空間的遅延が存在する。波長 λ によって、この空間的遅延は、$(2\pi/\lambda)d \cdot \cos(\theta - \phi_m)$ によって定義される電気的角度差に変換される。従って、角度 θ のＤＯＡにおけるアレーアンテナ装置１００の操向ベクトルは、半径が $d = \lambda/4$ である場合、次式で定義される。

【００３６】

【数１８】

$$a(\theta) = \begin{bmatrix} 1 \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_1)\} \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_2)\} \\ \vdots \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_6)\} \end{bmatrix}$$

【００３７】上述の単純な場合を、より一般的な場合に拡張することができる。ＤＯＡが θ_q（q＝0，1，…，Q）である到来受信信号 $u_q(t)$ を送信する信号源が合計Q＋1個あると仮定する。$s_m(t)$（m＝0，1，…，6）はアンテナのｍ番目のアンテナ素子Ａｍで受信される信号を表し、また $s(t)$ をｍ番目の成分に $s_m(t)$ を有する列ベクトルであるとする。信号 $s_m(t)$ は、Q＋1個の信号源からの信号の重ね合わせである。

【００３８】

10

【数１９】

$$s_m(t) = \sum_{q=0}^{Q} a_m(\theta_q)u_q(t), \quad (m=0,1,\cdots,6)$$

【００３９】ここで、$a_m(\theta_q)$（m＝0，1，2，…，6）は、θ の代わりに θ_q を有する数１８の第ｍ成分である。このとき、アンテナ素子Ａｍに現れる列ベクトル $s(t)$ は、次式のように表すことができる。

【００４０】

【数２０】

$$s(t) = \sum_{q=0}^{Q} a(\theta_q)u_q(t)$$

【００４１】ここで、

【数２１】　$a(\theta_q) \equiv [a_0(\theta_q), a_1(\theta_q), a_2(\theta_q), \cdots, a_6(\theta_q)]^T$

は、θ の代わりに θ_q を有する数１８において定義された操向ベクトルである。数3から、アレーアンテナ装置１００の出力信号である受信信号 $y(t)$ は次式のように表記することができる。

【００４２】

【数２２】

$$y(t) = i^T s(t) = \sum_{q=0}^{Q} i^T a(\theta_q)u_q(t)$$

【００４３】電流ベクトル ｉ、及び従って受信信号 $y(t)$ は、数1のリアクタンスベクトル ｘ の関数である。

【００４４】次に、勾配に基づくアレーアンテナ装置１００の適応制御処理について説明する。この適応制御処理で使用している学習シーケンス信号 $r(t)$ は、相手先の送信機と受信機の双方に知られていると仮定する。表記法の約束を少し変更し、本実施形態では、以後も受信信号 $y(t)$ によってアレーアンテナ装置１００のＲＦ出力の等価低域通過信号を表記する。

【００４５】従来の最急勾配アルゴリズムで一般に使用される評価関数は、平均2乗誤差である。この誤差が2つの信号の差分を表すのに対して、相互相関係数は近似性を表すことは周知である。平均2乗誤差の代わりに、我々の適応制御処理では相互相関係数を採用している。ここにおける我々の目的は、アンテナの出力である受信信号 $y(t)$ と学習シーケンス信号 $r(t)$ の間の相互相関係数が可能な限り大きくなるような数1のリアクタンスベクトル ｘ を発見することにある。

【００４６】$y(n)$ 及び $r(n)$ を各々、受信信号 $y(t)$ 及び学習シーケンス信号 $r(t)$ の離散的時間サンプルであるＰ次元ベクトルと仮定する。時刻 ｎ における受信信号 $y(n)$ と学習シーケンス信号 $r(n)$ との間の相互相関係数は、次式のように定義される。

【００４７】

【数２３】

11

$$\rho_n = \frac{\left| y(n)r(n)^H \right|}{\sqrt{y(n)y(n)^H}\sqrt{r(n)r(n)^H}}$$

【００４８】ここで、上付き文字Hは複素共役をとる転置を表す。これにより、勾配ベクトルは次式のように定義される。

【００４９】

【数２４】

$$\nabla \rho_n \equiv \frac{\partial \rho_n}{\partial x} \equiv \begin{bmatrix} \dfrac{\partial \rho_n}{\partial x_1} \\ \dfrac{\partial \rho_n}{\partial x_2} \\ \vdots \\ \dfrac{\partial \rho_n}{\partial x_6} \end{bmatrix}$$

【００５０】ここで、$\partial \rho_n / \partial x$はリアクタンスベクトルxについての導関数を表す。

【００５１】最急勾配法によって相互相関係数を可能な限り大きくするような良好なリアクタンスベクトルxを発見するためには、以下の手順を用いる。

（ｉ）最初に、時刻ｎ（すなわち、ｎ回目の反復）を１に設定し、任意に選択したリアクタンスベクトルの初期値ｘ（１）によって開始する。典型的には、初期の指向性パターンが全方向性であるとき、リアクタンスベクトルの初期値ｘ（１）はゼロベクトルに等しく設定される。

（ｉｉ）次いで、この初期値又は現在の推定値を使用して、時刻ｎ（すなわち、ｎ回目の反復）における勾配ベクトル$\nabla \rho_n$を計算する。

（ｉｉｉ）勾配ベクトルの方向と同一の方向に初期値又は現在の推定値を変更することで、リアクタンスベクトルにおける次の推定値を計算する。

（ｉｖ）ステップ（ｉｉ）に戻って処理を繰り返す。

【００５２】詳しくは提案された適応制御処理のフロー図を表す図８を参照して以下のようなステップを実行する。この適応制御処理は、図１の復調器４２が無線通信を開始する前に、相手先の送信機からの学習シーケンス信号を含む無線信号を受信しているときに実行される。

【００５３】図８において、まず、ステップＳ１において、ｎ＝１に設定し、時刻ｎ（ｎ回目の反復）における数１のリアクタンスベクトルｘ（ｎ）を、任意に選択したリアクタンスベクトルの初期値ｘ（１）に設定する。次いで、ステップＳ２において、図８の内ループを開始する前に、パラメータｍ＝０とし、ステップＳ３において、受信信号ｙ（ｔ）を測定する。そして、ステップＳ４において、数２３を用いて相互相関係数ρ_nを計算し、上記相互相関係数ρ_nを摂動前の基準係数（非摂動の係数）$\rho_n^{(0)}$に代入する。さらに、ステップＳ５において、パラメータｍを１だけインクリメントし、ステップＳ６において、リアクタンスベクトルの第ｍ成分x_m

12

をΔx_mだけ摂動させる。そして、ステップＳ７において、受信信号ｙ（ｔ）を測定し、ステップＳ８において、数２３を用いて相互相関係数ρ_nを計算する。次いで、ステップＳ９において、相互相関係数のリアクタンスベクトルxについての傾きを示す導関数$\partial \rho_n / \partial x_i$を、$\rho_n - \rho_n^{(0)}$によって計算する。さらに、ステップＳ１０において、ステップＳ６で摂動させたリアクタンスベクトルの第ｍ成分x_mを元に戻す。そして、ステップＳ１１において、パラメータｍが無給電可変リアクタンス素子Ａ１乃至Ａ６の数Ｍ＝６よりも小さいか否かを判断し、ｍ＜Ｍのときは内ループでステップＳ５に戻る一方、ｍ≧ＭのときはステップＳ１２に進む。

【００５４】ステップＳ１２において、上述の最急勾配法に従って、再帰的関係を使用して次のように時刻ｎ＋１におけるリアクタンスベクトルxの更新値ｘ（ｎ＋１）を計算する。

【数２５】　$x(n+1) = x(n) + \mu \nabla \rho_n$

【００５５】ここで、μは収束速度を制御する正の定数であり、例えば$\mu = 150$に設定される。次いで、ステップＳ１３において、ｎを１だけインクリメントし、ステップＳ１４において、ｎが予め決定された反復回数Ｎに達していないかどうかを判断し、ｎ≦Ｎのとき外ループによりステップＳ２に戻る一方、ｎ＞Ｎのときは当該適応制御処理を終了する。以上の適応制御処理により、評価関数値を最大にするように収束させることができ、所望波の到来角度が未知でも、アレーアンテナの制御装置１００の主ビームを所望波に向けかつ干渉波にヌルを向けるように適応制御することができる。

【００５６】勾配ベクトルの正の方向に行なうリアクタンスベクトルxの連続的な補正は、相互相関係数が大きいという意味で結局は良好なリアクタンスベクトルxとなることは、直観的にも妥当である。

【００５７】数２４の勾配ベクトル$\nabla \rho_n$の計算に際しては、幾つか困難のある場合がある。上述のように、これは、（ａ）受信信号ｙ（ｔ）の表現における、取り扱いが難しい逆行列の演算の存在により、勾配ベクトルをリアクタンスベクトルxの関数として解析的に表すことは容易ではない（数３及び数５参照）、（ｂ）アレーアンテナ装置１００の給電アンテナ素子Ａ０及び無給電アンテナ素子Ａ１乃至Ａ６の各々で受信される信号ベクトルを観測できない、という事実に起因している。

【００５８】本実施形態において、数２４の勾配ベクトル$\nabla \rho_n$の推定値は、偏導関数の有限の差分による近似値の使用によって導出されている。特に、リアクタンスx_iに関する１階の偏導関数$\partial \rho_n / \partial x_i$が、リアクタンス$x_m$を$x_m + \Delta x_m$へと増分をとることによって相互相関係数$\rho_n$の変動値に近似される。

【００５９】

【数２６】

13　　　　　　　　　　　　　　　　　14

$$\frac{\partial \rho_n}{\partial x_m} \approx \rho_n(x_1, x_2, \cdots, x_m + \Delta x_m, \cdots x_6) - \rho_n(x_1, x_2, \cdots, x_m, \quad \cdots x_6), \quad m = 1, 2, \cdots, 6,$$

【００６０】この勾配ベクトルの評価を数２６に代入して、リアクタンスベクトルｘ（ｎ＋１）を算出する。これらのステップをｎ＝１からｎ＝Ｎまで繰り返し、十分大きいＮについて、相互相関係数ρₙが大きいという意味で良好なリアクタンスベクトルｘ（Ｎ＋１）を得る。

【００６１】数２６が示すように、アンテナの出力からは、一度にただ１つの勾配ベクトル∇ρₙの成分しか算出されない。リアクタンスベクトルｘの全成分を逐次的に摂動し、数２５の各反復に対して１つの勾配ベクトルを得る。図７は、使用した学習シーケンス信号ｒ（ｔ）の枠組み構造を示している。データブロックｒ（ｉ）（ｉ＝１，２，…，Ｎ）はそれぞれ、１と−１とからなる擬似ランダム信号であり、データブロックｒ（１），ｒ（２），…，ｒ（Ｎ）のそれぞれは、図８のステップＳ５からステップＳ１１までのループにおいて、相関係数の勾配ベクトルのＭ＋１個（本実施形態においてはＭ＝６）の成分を計算するためにＭ＋１回ずつ繰り返される、すなわち一度の繰り返しにＭ＋１回のデータブロックｒ（ｉ）の伝送を必要とする。ここで、Ｍ＋１回のデータブロックｒ（ｉ）は、１つの非摂動時に受信信号ｙ（ｔ）と、Ｍ個の摂動時の受信信号ｙ（ｔ）を測定するために用いられる。この場合、各データブロックのシンボル数ｒ（ｉ）をＰとすると、上記勾配ベクトルからリアクタンスの推定値を計算することをＮ回繰り返すので、学習シーケンス信号ｒ（ｔ）はＰ×（Ｍ＋１）×Ｎ個のシンボルからなる。

【００６２】以上説明したように、本発明に係る実施形態によれば、適応制御型コントローラ４０は、復調器４２による無線通信を開始する前に、相手先の送信機から送信される無線信号に含まれる学習シーケンス信号を上記アレーアンテナ装置１００の給電アンテナ素子Ａ０により受信したときの受信信号ｙ（ｔ）と、上記学習シーケンス信号と同一であり学習シーケンス信号発生器４１で発生された学習シーケンス信号ｒ（ｔ）とに基づいて、図８の適応制御処理を実行することにより上記アレーアンテナ装置１００の主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子Ａ１乃至Ａ６のリアクタンス値ｘ．（ｍ＝１，２，…，６）を計算して設定する。従って、本実施形態に係るアレーアンテナの制御装置又は制御方法は、ハミルトニアン法を用いた従来例に比較して、所望波の到来角度が未知でも所望波に主ビームを向けかつ干渉波にヌルを向けるように適応制御することができる。

【００６３】＜変形例＞以上の実施形態においては、６本の無給電可変リアクタンス素子Ａ１乃至Ａ６を用いているが、その本数は少なくとも複数本あれば、当該アレーアンテナ装置の指向特性を電子的に制御することができる。それに代わって、６個よりも多くの無給電可変リ

アクタンス素子を備えてもよい。また、無給電可変リアクタンス素子Ａ１乃至Ａ６の配置形状も上記の実施形態に限定されず、給電アンテナ素子Ａ０から所定の距離だけ離れていればよい。すなわち、各無給電可変リアクタンス素子Ａ１乃至Ａ６に対する間隔ｄは一定でなくてもよい。

【００６４】さらに、可変リアクタンス素子２３は可変容量ダイオードＤに限定されず、リアクタンス値を制御可能な素子であればよい。可変容量ダイオードＤは一般に容量性の回路素子なので、リアクタンス値は常に負の値となる。なお、表１の数値例では、インピーダンスＺとしてゼロや正の値を用いている。上記可変リアクタンス素子２３のリアクタンス値は、正から負の値までの範囲の値をとってもよく、このためには、例えば可変容量ダイオードＤに直列に固定のインダクタを挿入するか、もしくは、非励振素子７の長さをより長くすることにより、正から負の値までにわたってリアクタンス値を変化させることができる。

【００６５】以上の本実施形態においては、最急勾配法の評価関数として相互相関係数ρₙを用いたが、本発明はこれに限らず、他の関数を用いてもよい。その例として、２乗誤差基準と定包絡線基準について説明する。２乗誤差基準の評価関数は、次式で表される。

【００６６】

【数２７】$J = E[|r'(t) - y'(t)|^2]$

【００６７】ここで、｜・｜は複素数の絶対値を表し、Ｅ［・］はアンサンブル平均を表す。また、受信信号ｙ（ｔ）及び学習シーケンス信号ｒ（ｔ）は、次式のごとく正規化されている。

【００６８】

【数２８】$y'(t) = y(t) / |y(t)|$

【数２９】$r'(t) = r(t) / |r(t)|$

【００６９】２乗誤差基準の評価関数を用いるとき、適応制御型コントローラ４０は、評価関数値Ｊが最小となるように適応制御する。

【００７０】また、ＣＭＡアルゴリズムを用いた定包絡線基準の評価関数は、次式で表される。

【００７１】

【数３０】$J = E[||y'(t)|^2 - 1|^2]$

【００７２】ここでも受信信号ｙ（ｔ）は数２８と同じｙ'（ｔ）によって正規化されている。このときは学習シーケンス信号ｒ（ｔ）は不要であるが、受信信号の包絡線が一定値となるようなシステムでしか使用できない。それは、具体的にはＦＭ，ＢＰＳＫ，ＱＰＳＫ等の変調方式を採用するシステムである。定包絡線基準の評価関数を用いたとき、適応制御型コントローラ４０は、相手先の送信機から送信される無線信号をアレーアンテナ装置４０により受信したときの受信信号ｙ（ｔ）に基

15

づいて上記評価関数値を計算し、当該評価関数値が最小となるように制御し、上記評価関数は、上記受信信号の包絡線が一定値となるときに最小となる関数である。

【００７３】以上の実施形態においては、学習シーケンス信号ｒ（ｔ）を構成する各データブロックｒ（ｉ）（ｉ＝１，２，…，Ｎ）は、シンボル数Ｐ＝１０である擬似ランダム信号であったが、他のシンボル数の信号であってもよい。また、学習シーケンスを用いた適応制御処理は、通信の最初に行っても、ある時間周期毎に行ってもよい。

【００７４】

【実施例】さらに、本実施形態のアレーアンテナの制御装置を用いたシミュレーションとその結果について説明する。

【００７５】アレーアンテナ装置１００からの出力表現における逆行列の存在（数３及び数５参照）は、その性能の解析的に記述することを困難にすることが考えられる。提案されたアルゴリズム及びアンテナ性能を検証するためにシミュレーションを実施した。我々のシミュレーションでは、（６＋１）素子のエスパアンテナで構成されたアレーアンテナ装置１００を使用している。給電アンテナ素子Ａ０及び無給電リアクタンス素子Ａ１乃至Ａ６はそれぞれλ／４長のモノポール素子である。我々は、全ての到来信号ｕ．（ｔ）（ｑ＝０，１，…，Ｑ）のパワーを１となるように選択した。ノイズはないものと仮定した。全てのシミュレーションを通じて、数２３に定義された相互相関係数の各計算のためのデータブロックのシンボル数は、Ｐ＝１０に設定された。

【００７６】まず、異なる方向から２つの信号が存在するケースについて考える。入力信号対干渉波電力比（以下、信号対干渉波電力比をＳＩＲという。）は、到来信号が１のパワーである仮定により０ｄＢである。Ｎ＝８００の反復後は、図９に示すように、ビームは所望する信号の０°に向けられ、また、１３５°における干渉波信号に向けてより深いヌルが形成される。このとき、２８．２６ｄＢの出力ＳＩＲが取得される。図１０は、図９の指向性パターンを得たときの、反復回数ｎに対する相互相関係数ρ。の収束特性を示すグラフである。到来信号の学習に使用されたシンボル数は、

【数３１】Ｐ（Ｍ＋１）Ｎ＝１０×（６＋１）×８００＝５６０００
個である。

【００７７】次に、５つの到来信号が存在する場合について考察する。これらの到来信号のＤＯＡは［０°，４０°，５５°，２２０°，３０５°］であり、１つを所望された所望波信号とし、他の４つを干渉波信号として、－６．０２ｄＢの入力ＳＩＲを有している。指向性パターンを図１１乃至図１５に示す。図面はそれぞれ、所望波信号が０°，４０°，５５°，２２０°，３０５°から到来している状況に対応し、出力ＳＩＲはそれぞ

16

れ９．０９ｄＢ，－１．４１ｄＢ，２．６７ｄＢ，２０．０３ｄＢ，１０．２８ｄＢである。図１２及び図１３は、４０°と５５°の間の角度の分離が僅かである混雑したＤＯＡのケースに関する２つの指向性パターンを示している。両信号は主要ビームとなり、より低い値の出力ＳＩＲは性能を低下させる。ここで、図１２及び図１３からは、このように僅かな角度分離の場合でも、エスパアンテナの技術を適用され、かつ適応的に制御されるアレーアンテナ装置１００を使用すれば干渉効果を減少させ、ＳＩＲ利得（即ち、出力と入力とのＳＩＲ差）を各々約４．６０ｄＢ及び８．６９ｄＢ向上できる。図１１乃至図１５のこれらのパターンは、Ｎ＝１０００の反復の後に取得される。学習シーケンスにおけるシンボル数は、合計（７×１０⁴）である。図１６は、図１１の指向性パターンを得たときの、反復回数ｎに対する相互相関係数ρ。の収束特性を示すグラフである。

【００７８】次に、図１１に示されたグラフのシミュレーションと同一のＤＯＡ及び入力ＳＩＲを有する５つの信号源からの到来信号の適応制御処理を、反復回数を減らして（Ｎ＝１００）再現する。図１７が示すように、ビームは所望される角度０°に向かって形成され、他のＤＯＡ（すなわち４０°，５５°，２２０°及び３０５°）からの干渉波信号は抑圧されている。このように少ない反復回数であっても、６．５８ｄＢの出力ＳＩＲはなおも確立されている。図１８は、図１７の指向性パターンを得たときの、反復回数ｎに対する相互相関係数ρ。の収束特性を示すグラフである。

【００７９】最後に、エスパアンテナの技術を適用され、かつ適応的に制御されるアレーアンテナ装置１００の出力ＳＩＲの統計的性能について考察する。図１９（Ｎ＝４０のとき）及び図２０（Ｎ＝１０００のとき）は、Ｚで表される出力ＳＩＲが横座標の与えられた実数ｚを越える確率Ｐｒ（Ｚ≧ｚ）を示している。これらの図面に関わる計算に際しては、所望された信号は角度０°から到来するものとし、干渉波信号のＤＯＡは０°乃至３５９°の範囲で一様にランダムであるように設定している。これらの統計では、１０００セットのＤＯＡを全て使用している。曲線は、干渉波信号の数Ｑ＝１，２，３及び４のケースが描かれている。これらの曲線をどう解釈するかについての例として、図２０は、Ｑ＝４の場合に、この適応型アンテナが少なくとも２０ｄＢの出力ＳＩＲ（言い替えれば２６．０２ｄＢのＳＩＲ利得）を８０％の確率で供給可能であることを含意している。図１９と図２０を比較すると、より多い反復回数が、本実施形態のアレーアンテナ装置１００の出力ＳＩＲを増大させることが分かる。

【００８０】以上で説明した我々の適応制御アルゴリズムは、アンテナ出力と学習シーケンス信号との間の相互相関係数が大きいという意味で良好な解法を得ている。実施例のシミュレーションで示したように、エスパアン

17

テナの技術を適用されたアレーアンテナ装置１００の場合、提案された適応制御アルゴリズムによるＳＩＲの改善は、幾つかの実際的状況において受容可能なものである。すなわち、７素子のアレーアンテナ装置１００が少なくとも約２６ｄＢのＳＩＲ利得を８０％の確率で供給できることを示している。本発明に係る適応制御処理のアルゴリズムの開発は、複雑性の低いエスバアンテナの技術を、無線移動体の端末等に適応可能であり、適用可能なものにしている。

【００８１】
【発明の効果】以上詳述したように本発明に係るアレーアンテナの制御装置によれば、従来技術のエスバアンテナの制御装置において、各可変リアクタンス素子のリアクタンス値を順次所定のシフト量だけ摂動させ、各リアクタンス値に対する所定の評価関数値の傾斜ベクトルを計算し、計算された傾斜ベクトルに基づいて当該評価関数値が最大又は最小となるように、上記アレーアンテナの主ビームを所望波の方向に向けかつ干渉波の方向にヌルを向けるための各可変リアクタンス素子のリアクタンス値を計算して設定する。従って、ハミルトニアン法を用いた従来例に比較して、所望波の到来角度が未知でも所望波に主ビームを向けかつ干渉波にヌルを向けるように適応制御することができる。特に、ハミルトニアン法を用いた従来例では、干渉波にヌルを向けることができないが、本発明では、干渉波にヌルを向けることができるという特有の効果を有する。

【００８２】当該アレーアンテナの制御装置は、例えば、移動体通信端末用のアンテナとしてノートパソコンやＰＤＡのような電子機器へ装着が容易であり、また、水平面のどの方向へ主ビームを走査した場合でも、すべての無給電可変リアクタンス素子が導波器又は反射器として有効に機能し、到来波および複数の干渉波に対する指向特性の制御もきわめて好適である。

【図面の簡単な説明】
【図１】　本発明に係る実施形態であるアレーアンテナの制御装置の構成を示すブロック図である。
【図２】　図１のアレーアンテナ装置１００の構成を表す斜視図である。
【図３】　図１の給電アンテナ素子Ａ０の構成を示す模式図である。
【図４】　図１の無給電可変リアクタンス素子Ａ１乃至Ａ６の構成を示す模式図である。
【図５】　図２のアレーアンテナ装置１００の詳細な構成を示す断面図である。
【図６】　図１のアレーアンテナ装置１００の構成を表す平面図である。
【図７】　図１の学習シーケンス信号発生器４１によって発生される学習シーケンス信号の構成を示すシーケンス図である。
【図８】　図１の適応制御コントローラ４０によって実

18

行される適応制御処理を示すフローチャートである。
【図９】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が２つの場合の指向性パターンを示すグラフである。
【図１０】　図９の指向性パターンを得たときの、反復回数ｎに対する相互相関係数ρ_nの収束特性を示すグラフである。
【図１１】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が５つで０°方向を所望波信号とする場合の水平面指向性パターンである。
【図１２】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が５つで４０°方向を所望波信号とする場合の水平面指向性パターンを示すグラフである。
【図１３】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が５つで５５°方向を所望波信号とする場合の水平面指向性パターンを示すグラフである。
【図１４】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が５つで２２０°方向を所望波信号とする場合の水平面指向性パターンを示すグラフである。
【図１５】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が５つで３０５°方向を所望波信号とする場合の水平面指向性パターンを示すグラフである。
【図１６】　図１１の指向性パターンを得たときの、反復回数ｎに対する相互相関係数ρ_nの収束特性を示すグラフである。
【図１７】　図１のアレーアンテナの制御装置のシミュレーション結果であって、信号源が５つで０°方向を所望波信号とする場合の水平面指向性パターンを示すグラフである。
【図１８】　図１７の指向性パターンを得たときの、反復回数ｎに対する相互相関係数ρ_nの収束特性を示すグラフである。
【図１９】　図１のアレーアンテナの制御装置で、反復回数が４０回であるときの出力ＳＩＲが横軸の値を超える確率を示すグラフである。
【図２０】　図１のアレーアンテナの制御装置で、反復回数が１０００回であるときの出力ＳＩＲが横軸の値を超える確率を示すグラフである。
【符号の説明】
Ａ０…給電アンテナ素子、
Ａ１乃至Ａ６…無給電可変リアクタンス素子、
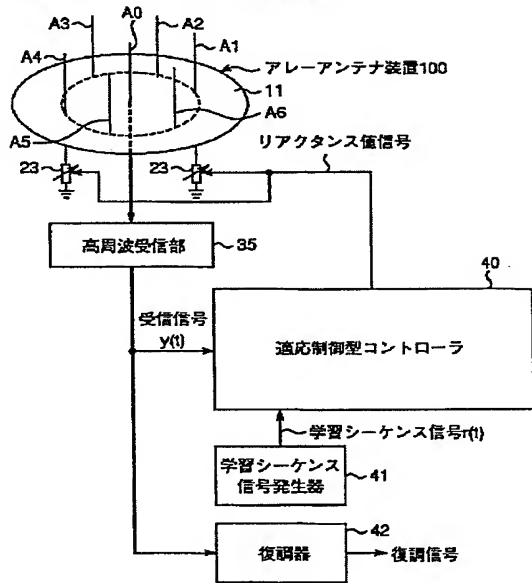Ｃ…キャパシタ、
Ｄ…可変容量ダイオード、
Ｒ…抵抗、
Ｔ…端子、
６…放射素子、

19

7…非励振素子、
10…誘電体基板、
11…接地導体、
12，13…スルーホール導体、
20…給電用同軸ケーブル、
21…中心導体、
22…外部導体、

20

＊２３…可変リアクタンス素子、
30…可変電圧直流電源、
35…高周波受信部、
40…適応制御型コントローラ、
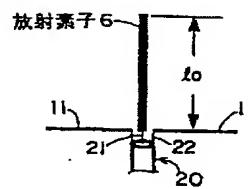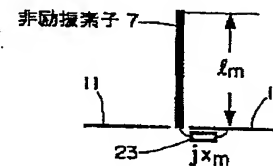41…学習シーケンス信号発生器、
42…復調器、
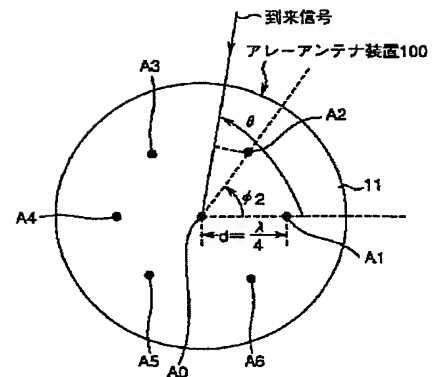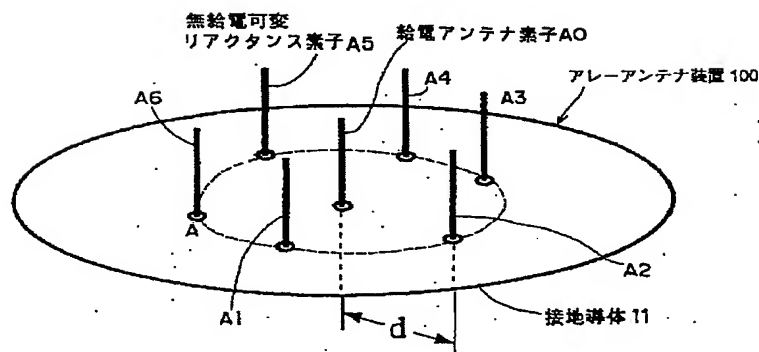＊　100…アレーアンテナ装置。

【図１】

実施形態　アレーアンテナの制御装置

【図３】

給電アンテナ素子AO

【図４】

無給電可変リアクタンス素子A1〜A6

【図２】

【図６】

【図５】

【図７】

学習シーケンス信号r(t)

| r(1) | r(1) | ... | r(1) | r(2) | r(2) | ... | r(2) | | r(n) | r(n) | ... | r(n) | ... | r(N) | r(N) | ... | r(N) |

(M+1)個のr(1)信号　　(M+1)個のr(2)信号　　(M+1)個のr(n)信号　　(M+1)個のr(N)信号

(M+1)×N個のr(t)信号

→ t

【図８】

適応制御処理

S1　$n \leftarrow 1$
　　$x(1) \leftarrow x(1)$の初期値

S2　$m \leftarrow 0$

S3　受信信号y(n)を測定する

S4　数23を用いて相互相関
　　係数ρ_nを計算する
　　$\rho_n^{(0)} \leftarrow \rho_n$

S5　$m \leftarrow m+1$

S6　$x_m \leftarrow x_m + \Delta x_m$

S7　受信信号y(n)を測定する

S8　数23を用いて相互相関
　　係数ρ_nを計算する

S9　$\dfrac{\partial \rho_n}{\partial x_m} \leftarrow \rho_n - \rho_n^{(0)}$

S10　$x_m \leftarrow x_m - \Delta x_m$

S11　$m < M$?　YES

S12　$x(n+1) \leftarrow x(n) + \mu \nabla \rho_n$

S13　$n \leftarrow n+1$

S14　$n \leqq N$?　YES

終了

【図１０】
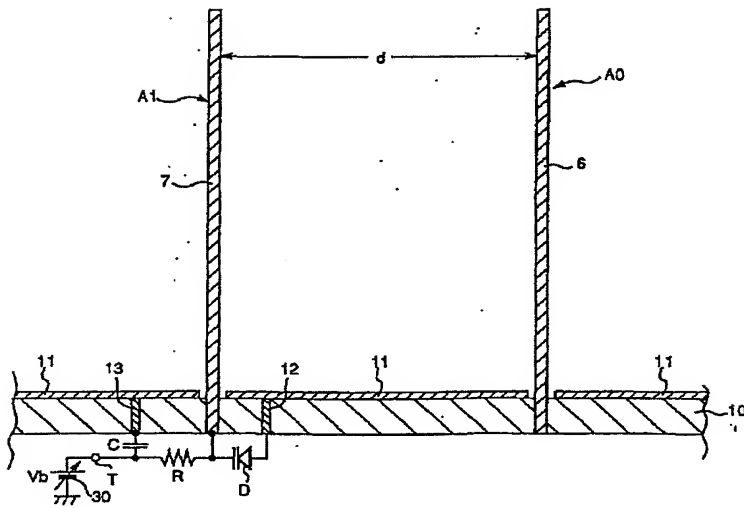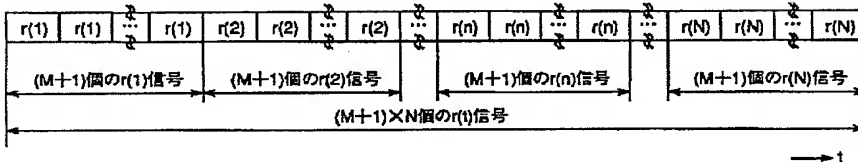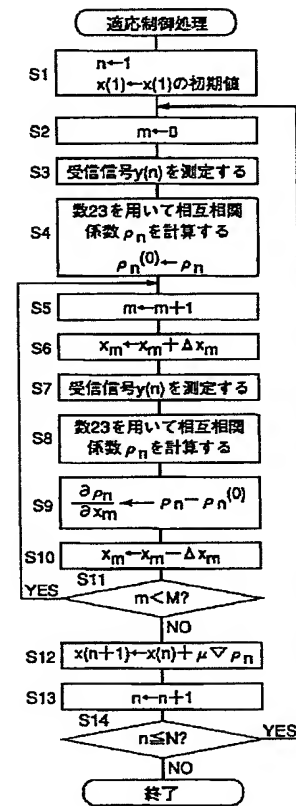
P=10
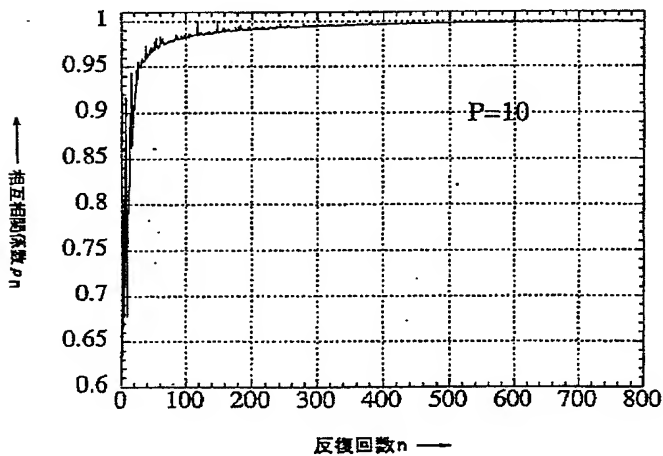
【図９】

N＝８００の時の指向性パターン

所望波：０°
干渉波：135°

入力ＳＩＲ　＝０dB
出力ＳＩＲ＝28.26dB
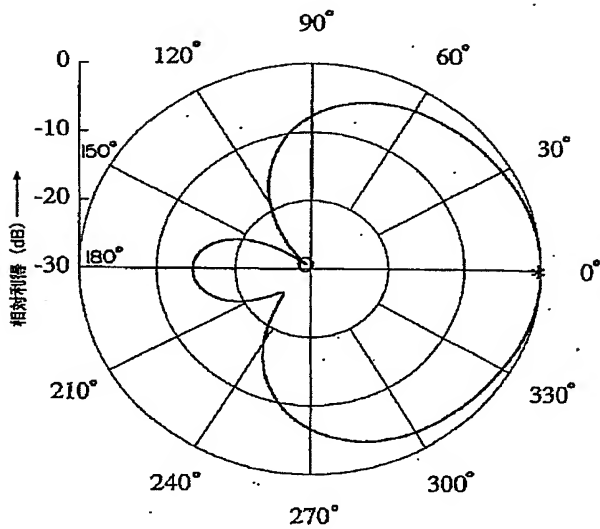
【図１１】

N＝１０００の時の指向性パターン

所望波：０°
干渉波：40°,55°,220°,305°

入力ＳＩＲ　＝－6.02dB
出力ＳＩＲ＝9.09dB
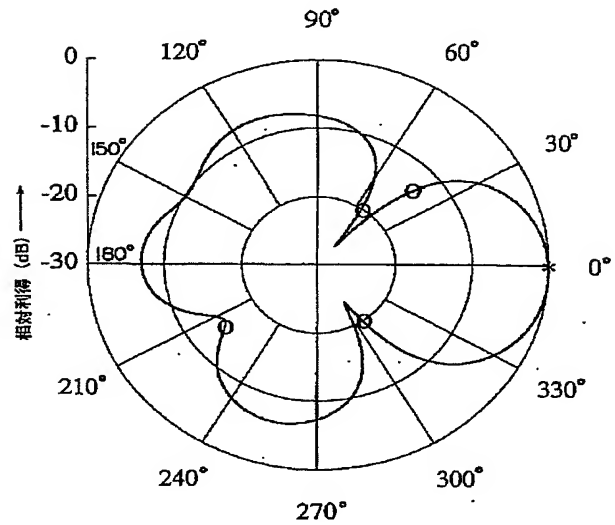
【図１２】

N＝１０００の時の指向性パターン

所望波：40°
干渉波：0°,55°,220°,305°

入力ＳＩＲ　＝－6.02dB
出力ＳＩＲ＝－1.41dB
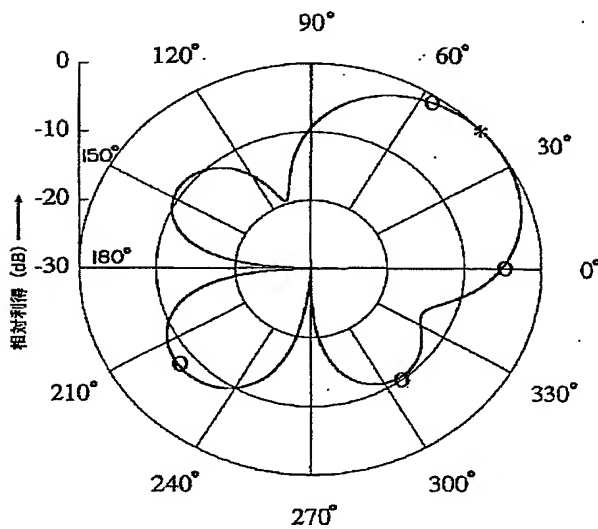
【図１３】

N＝１０００の時の指向性パターン

所望波：55°
干渉波：0°,40°,220°,305°

入力ＳＩＲ　＝－6.02dB
出力ＳＩＲ＝2.67dB
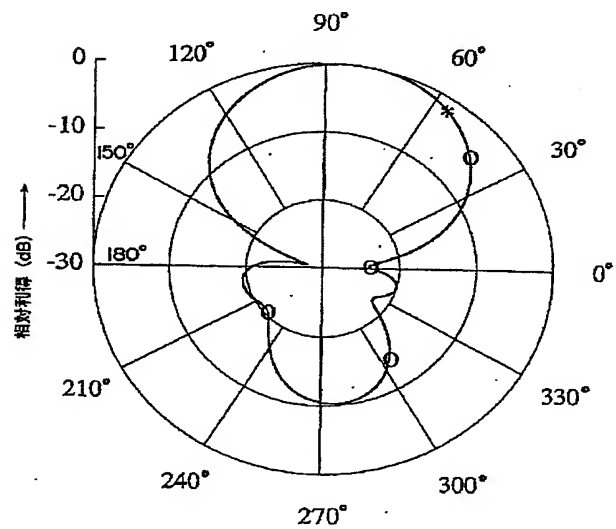
【図１４】
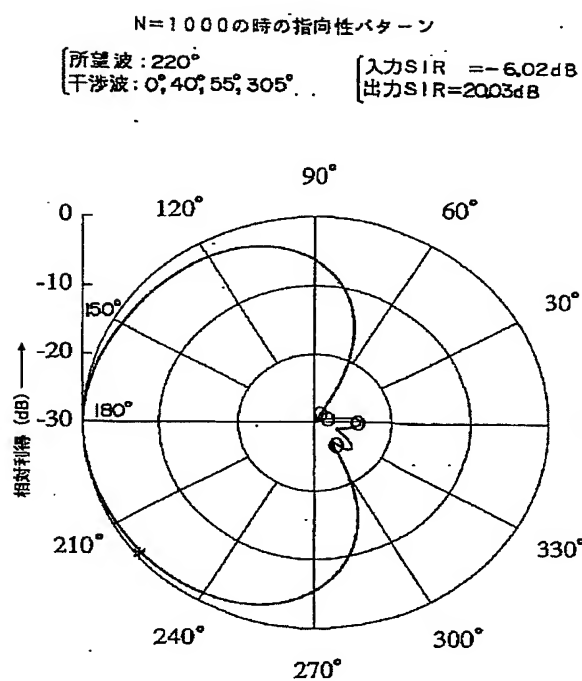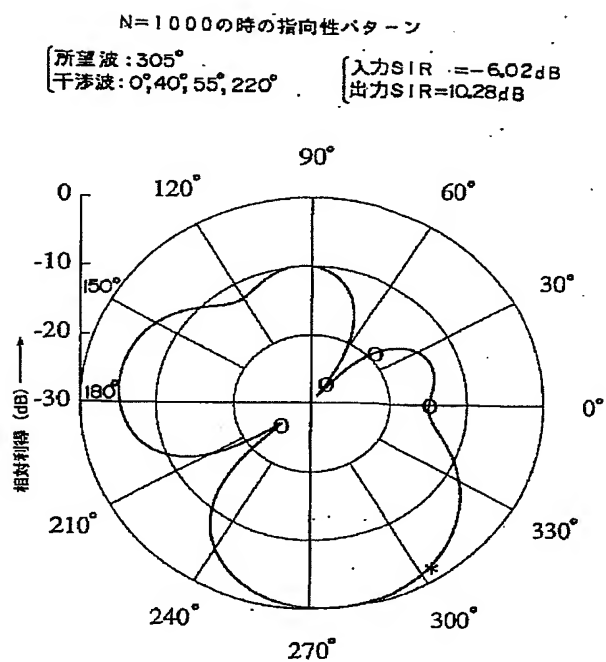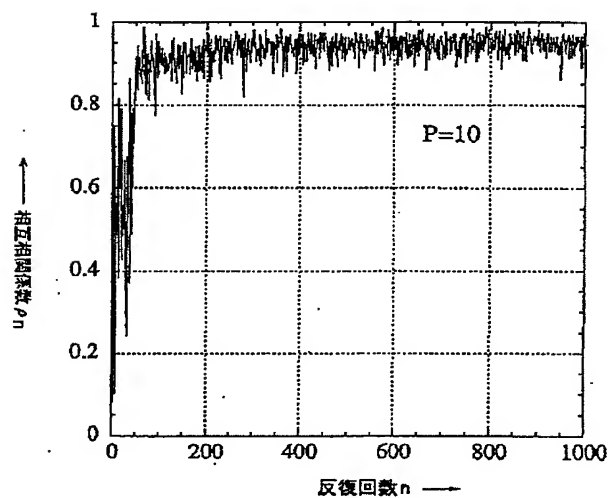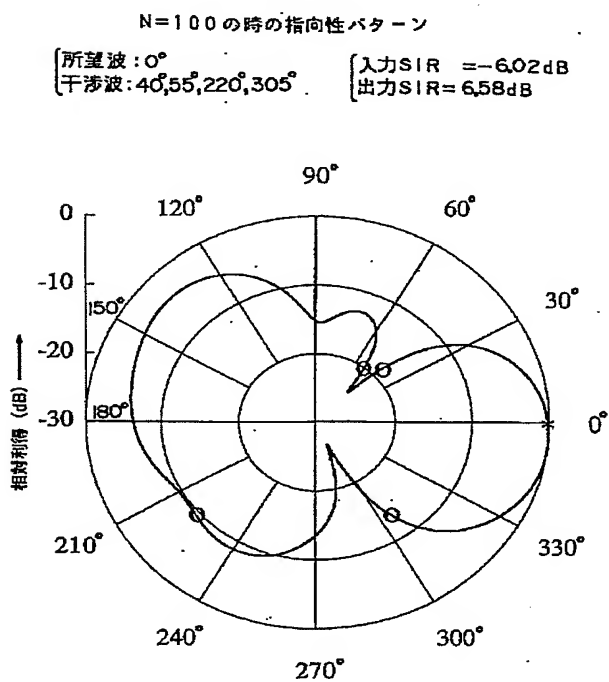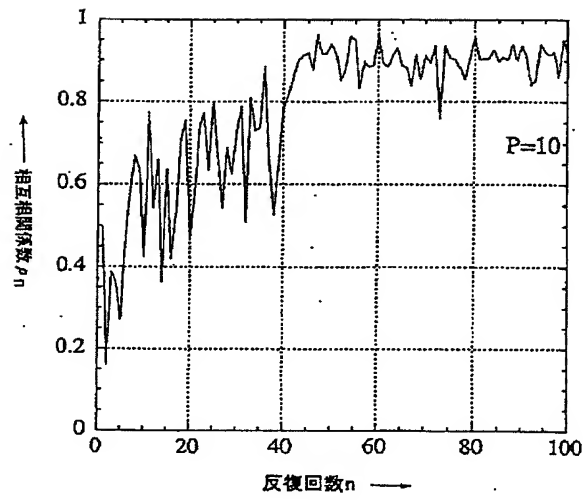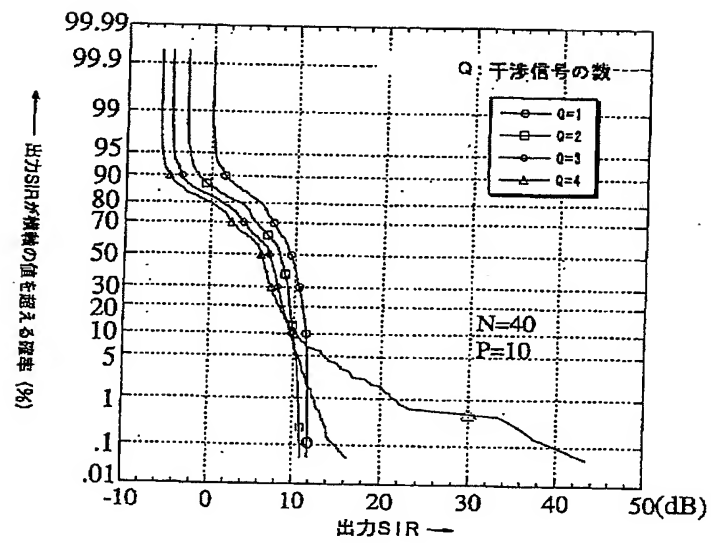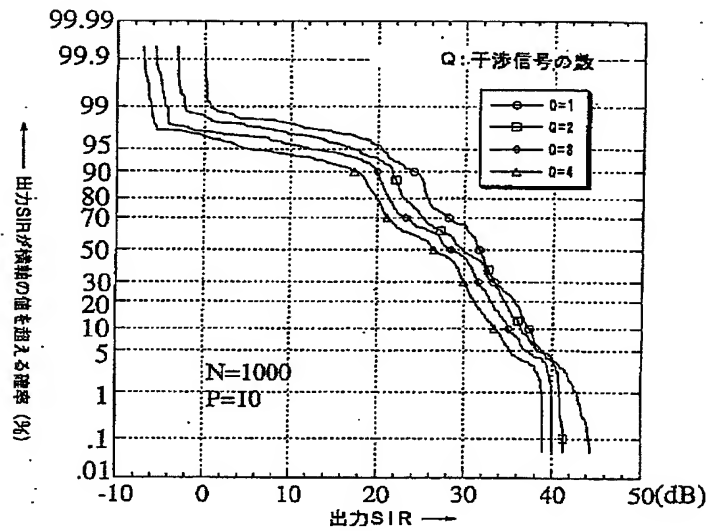
N＝１０００の時の指向性パターン

所望波：220°
干渉波：0°, 40°, 55°, 305°

入力ＳＩＲ ＝－6.02dB
出力ＳＩＲ＝20.03dB

相対利得 (dB)

【図１５】

N＝１０００の時の指向性パターン

所望波：305°
干渉波：0°, 40°, 55°, 220°

入力ＳＩＲ ＝－6.02dB
出力ＳＩＲ＝10.28dB

相対利得 (dB)

【図１６】

相互相関係数 ρn

P＝10

反復回数n ——→

【図１７】

N＝１００の時の指向性パターン

所望波：0°
干渉波：40°, 55°, 220°, 305°

入力ＳＩＲ ＝－6.02dB
出力ＳＩＲ＝6.58dB

相対利得 (dB)

【図１８】

【図１９】

【図２０】

JAPANESE   [JP,2002-118414,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE
INVENTION TECHNICAL PROBLEM MEANS EXAMPLE DESCRIPTION OF DRAWINGS
DRAWINGS

[Translation done.]

CLAIMS

[Claim(s)]
[Claim 1] The radiating element for receiving a radio signal, and two or more parasitic elements
in which only predetermined spacing was left and prepared from the above-mentioned radiating
element, By having two or more variable reactive elements connected to two or more above-
mentioned parasitic elements, respectively, and changing the reactance value of each above-
mentioned variable reactive element In the control unit of the array antenna to which two or
more above-mentioned variable reactive elements are operated as the wave director or a
reflector, respectively, and the directional characteristics of an array antenna are changed Only
a predetermined shift amount is made to precess the reactance value of each above-mentioned
variable reactive element one by one. So that the dip vector of the predetermined performance-
index value over each reactance value may be calculated and the performance-index value
concerned may serve as max or min based on the calculated dip vector The control unit of the
array antenna characterized by having the control means which calculates and sets up the
reactance value of each variable reactive element for turning the main beam of the above-
mentioned array antenna in the direction of a request wave, and turning null in the direction of
an interference wave.
[Claim 2] An input signal when the above-mentioned control means receives the study sequence
signal included in the radio signal transmitted from a phase hand's transmitter with the above-
mentioned array antenna, It is the same as that of the above-mentioned study sequence signal,
and the above-mentioned performance-index value is calculated based on the study sequence
signal generated in the control means concerned. It is the control unit of the array antenna
according to claim 1 which controls so that the performance-index value concerned serves as
max, and is characterized by the above-mentioned performance index being a cross correlation
function between the study sequence signals by which generating was carried out [above-
mentioned] with the above-mentioned input signal.
[Claim 3] An input signal when the above-mentioned control means receives the study sequence
signal included in the radio signal transmitted from a phase hand's transmitter with the above-
mentioned array antenna, It is the same as that of the above-mentioned study sequence signal,
and the above-mentioned performance-index value is calculated based on the study sequence
signal generated in the control means concerned. It is the control unit of the array antenna
according to claim 1 which controls so that the performance-index value concerned serves as
min, and is characterized by the above-mentioned performance index being a square error
between the study sequence signals by which generating was carried out [above-mentioned]
with the above-mentioned input signal.
[Claim 4] It is the control unit of the array antenna according to claim 1 which the above-
mentioned control means calculates the above-mentioned performance-index value based on an
input signal when the above-mentioned array antenna receives the radio signal transmitted from
a phase hand's transmitter, controls it so that the performance-index value concerned serves as
min, and is characterized by the above-mentioned performance index being a function which
serves as min when the envelope of the above-mentioned input signal serves as constant value.
[Claim 5] The radiating element for receiving a radio signal, and two or more parasitic elements

in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control approach of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed Only a predetermined shift amount is made to precess the reactance value of each above-mentioned variable reactive element one by one. So that the dip vector of the predetermined performance-index value over each reactance value may be calculated and the performance-index value concerned may serve as max or min based on the calculated dip vector The control approach of the array antenna characterized by including the step which calculates and sets up the reactance value of each variable reactive element for turning the main beam of the above-mentioned array antenna in the direction of a request wave, and turning null in the direction of an interference wave.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the control unit and the control approach of the
array antenna to which electronics control wave director array antenna equipment (it is called
ESUPA antenna below Electronically Steerable Passive Array Radiator (ESPAR) Antenna;.)
directional characteristics can be changed especially accommodative about the control unit and
the control approach of the array antenna to which the directional characteristics of the array
antenna equipment which consists of two or more antenna elements can be changed.
[0002]
[Description of the Prior Art] The ESUPA antenna of the conventional technique for example
"The conventional technical reference 1 T.Ohira et al. and "Electronically steerable passive
array radiator antennas for low-cost analog adaptive beamforming and "2000 IEEE International
Conference It is proposed in on PhasedArray System & Technology pp.101-104, Dana point,
California, May 21-25, and the patent application of 2000" and Japanese Patent Application No.
No. 194487 [11 to]. This ESUPA antenna can change the directional characteristics of the
above-mentioned array antenna by having the array antenna which consists of the radiating
element by which electric power is supplied to a radio signal, at least one parasitic element by
which only predetermined spacing is left and prepared from this radiating element, and electric
power is not supplied to a radio signal, and the variable reactive element connected to this
parasitic element, and changing the reactance value of the above-mentioned variable reactive
element.
[0003] As an approach for controlling the above-mentioned ESUPA antenna, in order to optimize
the reactance value of each variable reactive element in the patent application of an application
for patent No. 198560 [2000 to], a reactance value which makes antenna gain of the specified
azimuth max is calculated by having used Hamiltonian **.
[0004]
[Problem(s) to be Solved by the Invention] However, in this conventional example, whenever
[arrival angle / of an input signal] needed to be given beforehand, and there was a trouble that
it was not practical and null could not be turned to an interference wave.
[0005] It is in the object of this invention offering the control unit and the control approach of an
array antenna which can carry out adaptive control so that the above trouble is solved, it is not
necessary in control of an ESUPA antenna to give whenever [arrival angle / of an input signal]
beforehand, and the main beam may be turned to a request wave and null may be turned to an
interference wave.
[0006]
[Means for Solving the Problem] A radiating element for the control unit of the array antenna
concerning this invention to receive a radio signal, Two or more parasitic elements in which only
predetermined spacing was left and prepared from the above-mentioned radiating element, By
having two or more variable reactive elements connected to two or more above-mentioned
parasitic elements, respectively, and changing the reactance value of each above-mentioned
variable reactive element In the control unit of the array antenna to which two or more above-

mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed Only a predetermined shift amount is made to precess the reactance value of each above-mentioned variable reactive element one by one. So that the dip vector of the predetermined performance-index value over each reactance value may be calculated and the performance-index value concerned may serve as max or min based on the calculated dip vector It is characterized by having the control means which calculates and sets up the reactance value of each variable reactive element for turning the main beam of the above-mentioned array antenna in the direction of a request wave, and turning null in the direction of an interference wave.

[0007] In the control unit of the above-mentioned array antenna moreover, the above-mentioned control means An input signal when the above-mentioned array antenna receives the study sequence signal preferably included in the radio signal transmitted from a phase hand's transmitter, It is the same as that of the above-mentioned study sequence signal, and the above-mentioned performance-index value is calculated based on the study sequence signal generated in the control means concerned. It controls so that the performance-index value concerned serves as max, and the above-mentioned performance index is characterized by being a cross correlation function between the study sequence signals by which generating was carried out [above-mentioned] with the above-mentioned input signal.

[0008] In the control unit of the above-mentioned array antenna furthermore, the above-mentioned control means An input signal when the above-mentioned array antenna receives the study sequence signal preferably included in the radio signal transmitted from a phase hand's transmitter, It is the same as that of the above-mentioned study sequence signal, and the above-mentioned performance-index value is calculated based on the study sequence signal generated in the control means concerned. It controls so that the performance-index value concerned serves as min, and the above-mentioned performance index is characterized by being a square error between the study sequence signals by which generating was carried out [above-mentioned] with the above-mentioned input signal.

[0009] Furthermore, in the control unit of the above-mentioned array antenna, the above-mentioned control means calculates the above-mentioned performance-index value based on an input signal when the above-mentioned array antenna receives preferably the radio signal transmitted from a phase hand's transmitter, it controls it so that the performance-index value concerned serves as min, and it is characterized by the above-mentioned performance index being a function which serves as min when the envelope of the above-mentioned input signal serves as constant value.

[0010] Moreover, the control approach of the array antenna concerning this invention The radiating element for receiving a radio signal, and two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control approach of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed Only a predetermined shift amount is made to precess the reactance value of each above-mentioned variable reactive element one by one. So that the dip vector of the predetermined performance-index value over each reactance value may be calculated and the performance-index value concerned may serve as max or min based on the calculated dip vector It is characterized by including the step which calculates and sets up the reactance value of each variable reactive element for turning the main beam of the above-mentioned array antenna in the direction of a request wave, and turning null in the direction of an interference wave.

[0011]
[Embodiment of the Invention] Hereafter, the operation gestalt which starts this invention with reference to a drawing is explained.

[0012] Drawing 1 is the block diagram showing the configuration of the control device of the array antenna which is an operation gestalt concerning this invention. The control unit of the

array antenna of this operation gestalt is equipped with the array antenna equipment 100 which consisted of ESUPA antennas of the conventional technique which is equipped with one feed antenna element A0, six variable reactive elements A1 non-supplied electric power, or A6, and becomes, the adaptive control mold controller 40, and the study sequence signal generator 41 as shown in drawing 1 .

[0013] The adaptive control mold controller 40 consists of digital computers, such as a computer, here. Input-signal [before starting radiocommunication by the demodulator 42, when the feed antenna element A0 of the above-mentioned array antenna equipment 100 receives the study sequence signal included in the radio signal transmitted from a phase hand's transmitter] y (t), It is based on study sequence signal r (t) which is the same as that of the above-mentioned study sequence signal, and was generated with the study sequence signal generator 41. By performing adaptive control processing of drawing 8 It is characterized by calculating and setting up each variable reactive element A1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance value xm (m= 1, 2, --, 6) of A6. Specifically the adaptive control mold controller 40 Only predetermined shift-amount delta xm is made to precess each variable reactive element A1 thru/or the reactance value xm (m= 1, 2, --, 6) of A6 one by one. The predetermined performance index over each reactance value (with this operation gestalt) Calculate the dip vector of the value of cross-correlation-function rhon between study sequence signal r (t) by which generating was carried out [above-mentioned] with input-signal y (t) expressed with several 23, and so that the performance-index value concerned may serve as max based on the calculated dip vector Each variable reactive element A1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance value xm (m= 1, 2, --, 6) of A6 are calculated and set up.

[0014] In drawing 1 , the radio signal transmitted from a phase hand's transmitter is received by array antenna equipment 100, and the signal outputted from the feed antenna element A0 is transmitted to the adaptive control mold controller 40 and a demodulator 42 as input-signal y (t) through the RF receive section 35 which processes frequency conversion to low noise magnification, an intermediate frequency, or a berth band etc. After carrying out adaptive control of the above-mentioned adaptive control mold controller 40 so that above-mentioned adaptive control processing may be performed, and the main beam of the control device 100 of an array antenna may be turned in the direction of a request wave and null may be turned in the direction of an interference wave, radiocommunication by the demodulator 42 is started. Here, to received input-signal y (t), a demodulator 42 performs processing of a recovery etc., and acquires and outputs a recovery signal.

[0015] First, the configuration of the array antenna equipment 100 which consisted of ESUPA antennas with reference to drawing 2 thru/or drawing 5 is explained. As shown in drawing 2 , in array antenna equipment 100 The feed antenna element A0, It insulates from a conductor 11 electrically. the conductor with which six variable reactive elements A1 non-supplied electric power thru/or A6 have a size large enough to each nothing feed variable reactive element A0 thru/or the die length lo and lm (m= 1, 2, --, 6) of A6, respectively -- the touch-down which becomes with a plate -- And it is prepared so that the variable reactive element A1 non-supplied electric power thru/or A6 may be mutually arranged at intervals of the 60 same degrees in the location of the circular configuration of radius d=lambda / 4 (however, lambda wavelength) centering on the feed antenna element A0. Here, array antenna equipment 100 is a reversible circuit, and when using as a transmitting antenna, while electric power is supplied to a radio signal by only the feed antenna element A0, when using as a receiving antenna, the radio signal from a phase hand's transmitter is received by the feed antenna element A0 as input-signal y (t).

[0016] drawing 3 -- setting -- the feed antenna element A0 -- for example, the die length lo of lambda/4 of predetermined longitudinal directions -- having -- touch-down -- it has the cylindrical shape-like radiating element 6 insulated electrically [a conductor 11], and the central conductor 21 of the coaxial cable 20 which transmits the radio signal received by the radiating

element 6 is connected to the end of a radiating element 6 -- having -- the outer conductor 22 -- touch-down -- it connects with a conductor 11. This transmits further the radio signal received by the radiating element 6 to the adaptive control mold controller 40 and a demodulator 42 through the RF receive section 35 through a coaxial cable 20.

[0017] drawing 4 -- setting -- each nothing feed variable reactive element A1 thru/or A6 -- respectively -- for example, the die length lm (m= 1, 2, --, 6) of lambda/4 of predetermined longitudinal directions -- having -- touch-down -- it has the parasitic element 7 of the shape of a cylindrical shape insulated electrically [a conductor 11], and the variable reactive element 23 which has the reactance value xm (m= 1, 2, --, 6), and it has the same structure and is constituted. here -- the end of a parasitic element 7 -- a variable reactive element 23 -- minding -- touch-down -- it is grounded in RF to a conductor 11. For example, when the die length of the longitudinal direction of a radiating element 6 and a parasitic element 7 assumes substantially that it is the same (for example, when a variable reactive element 23 has inductance nature (L nature)), a variable reactive element 23 serves as an extension coil, and the variable reactive element A1 non-supplied electric power thru/or the electric merit of A6 become long as compared with the feed antenna element A0, and it works as a reflector. On the other hand, when a variable reactive element 23 has capacitance nature (C nature), a variable reactive element 23 serves as a loading condenser, and the variable reactive element A1 non-supplied electric power thru/or the electric merit of A6 become short as compared with the feed antenna element A0, and it works as the wave director. In actual application, Reactance xm can be restrained in fixed range, such as until −300ohm to 300ohm.

[0018] Drawing 5 is the sectional view showing the detailed configuration of the array antenna equipment 100 of drawing 1 , and variable-capacitance-diode D is used for it as a variable reactive element 23 with the desirable operation gestalt of drawing 5 .

[0019] drawing 5 -- setting -- for example, the top face of the dielectric substrates 10, such as a polycarbonate, -- touch-down -- a conductor 11 forms -- having -- a radiating element 6 -- touch-down -- insulating from a conductor 11 electrically, the dielectric substrate 10 is penetrated in the thickness direction, and it is supported. moreover, the parasitic element 7 -- touch-down -- insulating from a conductor 11 electrically, the dielectric substrate 10 is penetrated in the thickness direction, and it is supported. the through hole which comes to carry out restoration formation by the end of a parasitic element 7 penetrating variable-capacitance-diode D and the dielectric substrate 10 in the thickness direction here -- a conductor 12 -- minding -- touch-down -- while being grounded by the conductor 11 in RF, it connects with Terminal T through Resistance R. moreover, the through hole which comes to carry out restoration formation by Terminal T penetrating the capacitor C for a high frequency bypass, and the dielectric substrate 10 in the thickness direction -- a conductor 13 -- minding -- touch-down -- it is grounded by the conductor 11 in high frequency.

[0020] Adjustable electrical-potential-difference DC power supply 30 by which armature-voltage control is carried out by the adaptive control mold controller 40 are connected to Terminal T, and the electrostatic-capacity value in variable-capacitance-diode D is changed to it by changing by this the reverse bias electrical potential difference impressed to variable-capacitance-diode D. The electric merit of the variable reactive element A1 equipped with the parasitic element 7 non-supplied electric power can be changed by this as compared with the feed antenna element A0, and the flat-surface directivity property of the array antenna equipment 100 concerned can be changed. Furthermore, the variable reactive element A2 equipped with other parasitic elements 7 non-supplied electric power thru/or A6 are constituted similarly, and has the same operation.

[0021] The array antenna equipment 100 constituted as mentioned above is called an ESUPA antenna. With this operation gestalt, the control unit and the control approach for controlling the flat-surface directivity property of the whole array antenna equipment 100 accommodative are offered by changing further the reactance value of the variable reactive element 23 connected to each nothing feed [variable reactive element A1 thru/or A6 in the array antenna equipment 100 of drawing 1 .

[0022] The reactance value signal which is an output signal from the adaptive control mold

controller 40 for the array antenna equipment 100 which consisted of ESUPA antennas is simply formulized as a function of these six reactances. [Equation 1] which has the reactance value of each variable reactive element 23 as a component with this operation gestalt Since a reactance vector, and a call and the above-mentioned reactance vector are adjustable, the vector expressed with $x^{**}[x1, x2, --, x6]$ T is used for formation of the directivity response pattern of array antenna equipment 100.

[0023] It sets in this operation gestalt and is [Equation 2] about signal vector s (t). Defining by s(t) =[s0 (t), s1 (t), --, s6 (t)] T, Component sm (t) is a RF signal received by the m-th antenna element (m= 0, 1, --, 6) Am (namely, a feed antenna element or the reactive element non-supplied electric power) of array antenna equipment 100, and superscript T expresses transposition of a vector or a matrix. next, input-signal y (t) which is RF output signal of the single port of array antenna equipment 100 -- (-- the following principle explanation -- explanation -- the RF signal (RF signal) in the preceding paragraph of the RF receive section 35 is said for convenience.) -- it is given by the degree type.

[Equation 3] y(t)=iTs(t)

It is here and is [Equation 4]. i=[i0, i1, i2, --, i6] T is a vector which has RF current which appears on the m-th antenna element Am as a component im.

[0024] According to the electromagnetic-field analysis of array antenna equipment 100, RF current phasor i is formulized like a degree type.

[Equation 5] i=(I+jYX)−1y0[0025] Here, I is the unit matrix of x (6+1) (6+1), and is a diagonal matrix [several 6]. X=diag [x0, x1, x2, --, x6]

It is called ** and a reactance matrix. The input impedance x0 of the adaptive control mold controller 40 and a demodulator 42 is fixed, and it is assumed to be x0=0 with this operation gestalt, without losing generality. Furthermore, at several 5, a vector y0 is [Equation 7]. It defines by y=[0] [y00, y10, y20, --, y60] T, and is [Equation 8]. Y=[ykl] (6+1) x (6+1) shall be the admittance matrix of x (6+1) (6+1). Here, Component ykl expresses the mutual admittance between antenna elements Ak and aluminum (0<=k, l<=6).

[0026] (6+1) In the case of the array antenna equipment 100 of a component, a vector y0 and admittance-matrix Y are determined only of six components of mutual admittance. This is explained below.

[0027] By the well-known reciprocity theorem, a degree type is realized like the array antenna equipment of an ordinary type.

[Equation 9] ykl=ylk [0028] Furthermore, the patrol symmetric property of the antenna element Am of array antenna equipment 100 connotes the degree type.

[0029]

[Equation 10] y11=y22=y33=y44=y55=y66 -- [Equation 11] y01=y02=y03=y04=y05=y06 -- [Equation 12] y12=y23=y34=y45=y56=y61 -- [Equation 13] y13=y24=y35=y46=y51=y62 -- [Equation 14] y14=y25=y36[0030] Nine above thru/or several 14 mean that several 8 admittance matrix is determined only by six components y00, y10, y11, y21, y31, and y41 of mutual admittance. As for this, therefore, the value of six components is fixed depending on the physical structure of antennas, such as a radius of an antenna element Am, space spacing, and die length. Old explanation is summarized and admittance-matrix Y in several 5 is written like a degree type.

[0031]

[Equation 15]

$$
Y = \begin{bmatrix}
y_{00} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} \\
y_{10} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} \\
y_{10} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} \\
y_{10} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} \\
y_{10} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} \\
y_{10} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} \\
y_{10} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11}
\end{bmatrix}
$$

[0032] Similarly, several 7 can be rewritten as follows.

[Equation 16] Y=[y00, y10, y10, ─, y10] T [0033] That signal vector s (t) in several 3 received by the antenna element of array antenna equipment 100 cannot measure is the point which should be emphasized. This differs from the usual ecad array antenna with which the signal vector received on an antenna element is observed. In the case of array antenna equipment 100, it is measurable in input-signal y (t) which is a single-port output, and is used as feedback by which only this controls the reactance vector x of a-one number. Though still more regrettable, as shown in several 5, input-signal y (t) which is a single-port output is the high order nonlinear function of the reactance vector x, the operation of an inverse matrix is included and this makes generation of an analytical expression of adaptability ability difficult. Moreover, it should be warned that current phasor i in several 5 is also equivalent to the weighting-factor vector of the usual ecad array. Each component of join [together / unlike the weighting-factor vector of the usual ecad array / independently and mutually] of current phasor i is clear from several 5. The above-mentioned argument connotes that most control algorithms of the usual ecad array antenna cannot be directly applied to the array antenna equipment 100 to which the technique of an ESUPA antenna was applied. Therefore, it is desirable to propose the algorithm for adaptive control for an ESUPA antenna especially.

[0034] Subsequently, in order to make the array antenna equipment 100 of this operation gestalt into an ecad, the model of the signal received is proposed. Before advancing a study, the steering vector of array antenna equipment 100 is given. The array antenna equipment 100 of a component as shown in underline drawing 6 (6+1) is considered.

[0035] About the m-th antenna element Am, it is an include angle [several 17] to the shaft of arbitration.

phim=2pi (m-1) / 6 (m= 1, 2, ─, 6),

It comes out and arranges. The case of m= 2 is illustrated in drawing 6 . It comes from whenever [arrival angle / of an include angle theta] (DOA) by using the shaft of the above-mentioned arbitration as a reference axis, and when the wave front received on array antenna equipment 100 is observed, spatial delay of d-cos (theta-phim) exists between the signals which the pair of the m-th reactive element Am non-supplied electric power and the 0th feed antenna element A0 receives. This spatial delay is changed into the degree difference of electric target angle defined by d-cos (2 pi/lambda) (theta-phim) with wavelength lambda. Therefore, the steering vector of the array antenna equipment 100 in DOA of an include angle theta is defined by the degree type when radii are d=lambda/4.

[0036]
[Equation 18]

$$a(\theta) = \begin{bmatrix} 1 \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_1)\} \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_2)\} \\ \vdots \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_6)\} \end{bmatrix}$$

[0037] The above-mentioned case of being simple can be extended when more general. DOA assumes that there is a total of Q+a source of a signal which transmits the arrival input signal uq (t) which is thetaq (q= 0, 1, ─, Q). m= 0, and (1, ─, 6) express the signal received by the m-th antenna element Am of an antenna, and they presuppose that it is s (t) the column vector which has sm (t) for the m-th component. [sm (t) and] Signal sm (t) is the superposition of the signal from Q+1 source of a signal.

[0038]
[Equation 19]

$$s_m(t) = \sum_{q=0}^{Q} a_m(\theta_q)u_q(t), \quad (m=0,1,\cdots,6)$$

[0039] Here, am (m= 0, 1, 2, ─, 6) (thetaq) is the m-th component of several 18 which has

thetaq instead of theta. At this time, column vector s (t) which appears in an antenna element Am can be expressed like a degree type.

[0040]
[Equation 20]

$$s(t) = \sum_{q=0}^{Q} a(\theta_q) u_q(t)$$

[0041] It is here and is [Equation 21]. a(thetaq) **[a0 (thetaq), a1 (thetaq), a2 (thetaq), ――, a6 (thetaq)] T is the steering vector defined in several 18 which has thetaq instead of theta. From several 3, input-signal y (t) which is the output signal of array antenna equipment 100 can be written like a degree type.

[0042]
[Equation 22]

$$y(t) = i^T s(t) = \sum_{q=0}^{Q} i^T a(\theta_q) u_q(t)$$

[0043] current phasor i ―― and ―― therefore, input-signal y (t) is the function of the reactance vector x of several 1.

[0044] Next, the adaptive control processing of array antenna equipment 100 based on inclination is explained. It is assumed that study sequence signal r (t) currently used by this adaptive control processing is known by the both sides of the transmitter and receiver of a phase hand. A little convention of a notation is changed and henceforth writes the equivalence low pass signal of RF output of array antenna equipment 100 by input-signal y (t) with this operation gestalt.

[0045] The performance index generally used with the conventional maximum grade algorithm is a 2nd [an average of] power error. It is common knowledge that a cross correlation function expresses approximation nature to this error expressing the difference of two signals. Instead of an error, the cross correlation function is adopted by our adaptive control processing the 2nd [an average of] power. Our object in here is to discover the reactance vector x of several 1 to which the cross correlation function between input-signal y (t) which is the output of an antenna, and study sequence signal r (t) becomes as large as possible.

[0046] y (n) and r (n) are assumed to be the P-dimensional vectors which are the discrete time amount sample of input-signal y (t) and study sequence signal r (t) respectively. The cross correlation function between input-signal y (n) in time of day n and study sequence signal r (n) is defined like a degree type.

[0047]
[Equation 23]

$$\rho_n = \frac{\left| y(n) r(n)^H \right|}{\sqrt{y(n) y(n)^H} \sqrt{r(n) r(n)^H}}$$

[0048] Here, superscript H expresses the transposition which takes a complex conjugate. Thereby, a gradient vector is defined like a degree type.

[0049]
[Equation 24]

$$\nabla \rho_n \equiv \frac{\partial \rho_n}{\partial x} \equiv \begin{bmatrix} \dfrac{\partial \rho_n}{\partial x_1} \\ \dfrac{\partial \rho_n}{\partial x_2} \\ \vdots \\ \dfrac{\partial \rho_n}{\partial x_6} \end{bmatrix}$$

[0050] Here, **rhon/**x express the derivative about the reactance vector x.

[0051] The following procedures are used in order to discover the good reactance vector x

which enlarges a cross correlation function as much as possible by the maximum grade method.
(i) First, time of day n (namely, n-th iteration) is set as 1, and it starts with the initial value x of the reactance vector chosen as arbitration (1). Typically, when an early directivity response pattern is omnidirectional, the initial value x of a reactance vector (1) is set up equally to the zero vector.
(ii) Subsequently gradient vector **rhon in time of day n (namely, n-th iteration) is calculated by using this initial value or current estimate.
(iii) The following estimate in a reactance vector is calculated by changing initial value or current estimate in the same direction as the direction of a gradient vector.
(iv) It returns to a step (ii) and processing is repeated.
[0052] The following steps are performed with reference to drawing 8 showing flow drawing of the adaptive control processing proposed in detail. Before the demodulator 42 of drawing 1 starts radiocommunication, this adaptive control processing is performed when having received the radio signal including the study sequence signal from a phase hand's transmitter.
[0053] In drawing 8 , first, in step S1, it is set as n= 1 and the reactance vector x (n) of several 1 in time of day n (n-th iteration) is set as the initial value x of the reactance vector chosen as arbitration (1). Subsequently, in step S2, before starting the inner loop formation of drawing 8 , it considers as a parameter m= 0 and input-signal y (t) is measured in step S3. And in step S4, cross-correlation-function rhon is calculated using several 23, and the above-mentioned cross-correlation-function rhon is substituted for criteria multiplier (multiplier of non-perturbation) rho [before perturbation] n (0). Furthermore, only 1 increments Parameter m and only delta xm is made to precess the m-th component xm of a reactance vector in step S6 in step S5. And in step S7, input-signal y (t) is measured and cross-correlation-function rhon is calculated in step S8 using several 23. Subsequently, in step S9, derivative **rhon/**xi which shows the inclination about the reactance vector x of a cross correlation function is calculated by rhon-rhon (0). Furthermore, in step S10, the m-th component xm of a reactance vector made to precess at step S6 is returned. and the step S11 -- setting -- Parameter m -- several [the variable reactive element A1 non-supplied electric power thru/or / of A6] -- while judging whether it is smaller than M= 6 and returning to step S5 by the inner loop formation at the time of m<M, it progresses to step S12 at the time of m>=M.
[0054] In step S12, the updating value x (n+1) of the reactance vector x in time of day n+1 is calculated as follows using recursive relation according to an above-mentioned maximum grade method.
[Equation 25] x(n+1) = x (n) +mu**rhon [0055] Here, mu is a forward constant which controls a convergence rate, for example, is set as mu= 150. Subsequently, in step S13, only 1 increments n, and in step S14, while n judges whether the number of occurrence N determined beforehand is reached and returns to step S2 by the outside loop formation at the time of n<=N, the adaptive control processing concerned is ended at the time of n>N. Adaptive control can be carried out so that it can be made to converge so that a performance-index value may be made into max, the main beam of the control device 100 of an array antenna may be turned to a request wave even if whenever [arrival angle / of a request wave] is strange, and null may be turned to an interference wave by the above adaptive control processing.
[0056] It is intuitively appropriate to become the reactance vector x good after all in the semantics that the continuous amendment of the reactance vector x performed to the positive direction of a gradient vector has a large cross correlation function.
[0057] There are some difficult cases where it is, on the occasion of count of gradient vector **rhon of several 24. As mentioned above, this originates in the data that expressing a gradient vector analytically as a function of the reactance vector x cannot observe the signal vector received in the feed antenna element A0 of (b) array antenna equipment 100 which is not easy (several 3 and several 5 reference) and the parasitic antenna component A1 thru/or each of A6 by the existence of the operation of an inverse matrix with difficult handling in the expression of (a) input-signal y (t).
[0058] In this operation gestalt, the estimate of gradient vector **rhon of several 24 is drawn by the activity of the approximate value by the difference of the finite of a partial derivative.

Especially, partial-derivative **rhon/**xi of the first floor about Reactance xi is approximated to the variation of cross-correlation-function rhon by taking an increment to xm+delta xm in Reactance xm.

[0059]

[Equation 26]

$$\frac{\partial \rho_n}{\partial x_m} \approx \rho_n(x_1, x_2, \cdots, x_m + \Delta x_m, \cdots x_6) - \rho_n(x_1, x_2, \cdots, x_m, \quad \cdots x_6), \quad m = 1, 2, \cdots, 6,$$

[0060] The reactance vector x (n+1) is computed by substituting assessment of this gradient vector for several 26. These steps are repeated from n= 1 to n=N, and the good reactance vector x (N+1) is acquired in the semantics that cross-correlation-function rhoN is large, about sufficiently large N.

[0061] As shown in several 26, from the output of an antenna, only only one component of gradient vector **rhon is computed at once. All the components of the reactance vector x are serially precessed on a target, and one gradient vector is obtained repeatedly [each / of several 25]. Drawing 7 shows the framework structure of used study sequence signal r (t). N) is 1, 2, --, a pseudo-random signal that consists of 1 and -1, respectively. data block r (i) -- (-- i= -- each of data block r (1), r (2), --, r (N) In the loop formation from step S5 of drawing 8 to step S11, in order to calculate M+1 component (it sets in this operation gestalt and is M= 6) of the gradient vector of a correlation coefficient, are repeated by a unit of M+1 time. That is, M+1 transmission of data block r (i) is once needed for a repeat. Here, data block [M+1 time of] r (i) is used in order to measure input-signal y (t) and input-signal [at the time of M perturbation] y (t) at the time of one un-precessing. In this case, if number [of each data block] of symbols r (i) is set to P, since it will repeat calculating the estimate of a reactance from the above-mentioned gradient vector N times, study sequence signal r (t) consists of a symbol of a Px(M+1) xN individual.

[0062] As explained above, according to the operation gestalt concerning this invention, the adaptive control mold controller 40 Input-signal [before starting radiocommunication by the demodulator 42, when the feed antenna element A0 of the above-mentioned array antenna equipment 100 receives the study sequence signal included in the radio signal transmitted from a phase hand's transmitter] y (t), It is based on study sequence signal r (t) which is the same as that of the above-mentioned study sequence signal, and was generated with the study sequence signal generator 41. Each variable reactive element A1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance value xm (m= 1, 2, --, 6) of A6 are calculated and set up by performing adaptive control processing of drawing 8 . Therefore, as compared with the conventional example which used Hamiltonian **, even if whenever [arrival angle / of a request wave] is strange, adaptive control of the control unit or the control approach of an array antenna concerning this operation gestalt can be carried out so that the main beam may be turned to a request wave and null may be turned to an interference wave.

[0063] In the operation gestalt beyond a <modification>, although six variable reactive elements A1 non-supplied electric power thru/or A6 are used, if there are the two or more [at least] numbers, they can control the directional characteristics of the array antenna equipment concerned electronically. Instead of it, you may have many variable reactive elements non-supplied electric power rather than six pieces. Moreover, the variable reactive element A1 non-supplied electric power thru/or the arrangement configuration of A6 were not limited to the above-mentioned operation gestalt, either, but only a predetermined distance has separated it from the feed antenna element A0. That is, each nothing feed variable reactive element A1 thru/or the spacing d to A6 may not be fixed.

[0064] Furthermore, a variable reactive element 23 is not limited to variable-capacitance-diode D, but should just be a controllable component about a reactance value. Since variable-capacitance-diode D is generally a capacitive circuit element, a reactance value always turns into a negative value. In addition, in the numerical example of a table 1, zero and a forward value are used as an impedance Z. By being very good in the value of the range to a negative value from forward, and for that inserting the inductor of immobilization for example, in variable-

capacitance-diode D at a serial, or lengthening the die length of a parasitic element 7 more, it can go over the reactance value of the above-mentioned variable reactive element 23 by the negative value from forward, and it can change a reactance value.

[0065] In this above operation gestalt, although cross-correlation-function rhon was used as a performance index of a maximum grade method, this invention may use not only this but other functions. As the example, square error criteria and constant envelope criteria are explained. The performance index of square error criteria is expressed with a degree type.

[0066]

[Equation 27] $J=E[|r'(t)-y'(t)|2]$

[0067] Here, $|-|$ expresses the absolute value of complex and $E [-]$ expresses an ensemble average. Moreover, input-signal y (t) and study sequence signal r (t) are normalized like the degree type.

[0068]

[Equation 28] $y'(t) =y(t) y[/|] (t) |$ — [Equation 29] $r'(t) =r(t)/|r (t) |$ [0069] When using the performance index of square error criteria, adaptive control of the adaptive control mold controller 40 is carried out so that the performance-index value J may serve as min.

[0070] Moreover, the performance index of the constant envelope criteria of having used the CMA algorithm is expressed with a degree type.

[0071]

[Equation 30] $J=E[||y'(t)|2-1|2]$

[0072] Input-signal y (t) is normalized by the same y' (t) as several 28 also here. Although study sequence signal r (t) is unnecessary at this time, it can be used only by system by which the envelope of an input signal serves as constant value. It is a system which specifically adopts modulation techniques, such as FM, BPSK, and QPSK. The adaptive control mold controller 40 calculates the above-mentioned performance-index value based on input-signal [when array antenna equipment 40 receives the radio signal transmitted from a phase hand's transmitter] y (t), when the performance index of constant envelope criteria is used, it controls it so that the performance-index value concerned serves as min, and the above-mentioned performance index is a function used as min, when the envelope of the above-mentioned input signal serves as constant value.

[0073] each data block r (i) which constitutes study sequence signal r (t) in the above operation gestalt — (— i= — 1, 2, —, N) — several symbols — although it was the pseudo-random signal which is P= 10, you may be the signal of other numbers of symbols. Moreover, adaptive control processing using a study sequence may be performed to the communicative beginning, or you may carry out for every time period of a certain.

[0074]

[Example] Furthermore, the simulation using the control unit of the array antenna of this operation gestalt and its result are explained.

[0075] It is possible to make it difficult to describe analytically [the engine performance] existence (several 3 and several 5 reference) of the inverse matrix in the output expression from array antenna equipment 100. Simulation was carried out in order to verify the algorithm and antenna engine performance which were proposed. In our simulation, the array antenna equipment 100 which consisted of ESUPA antennas of a component (6+1) is used. The feed antenna element A0 and the reactive element A1 non-supplied electric power thru/or A6 are lambda/4 merit's monopole components, respectively. us — all the arrival signals uq (t) — (— q= — the power of 0, 1, —, Q) was chosen so that it might be set to 1. The noise assumed that it was what is not. The number of symbols of the data block for each count of the cross correlation function defined as several 23 was set as P= 10 through all simulation.

[0076] First, the case where two signals exist from a different direction is considered. An input signal pair interference wave power ratio (a signal pair interference wave power ratio is hereafter called SIR.) is 0dB by the assumption whose arrival signal is the power of 1. As after iteration of N= 800 is shown in drawing 9 , a beam is turned to 0 degree of the signal for which it asks, and deeper null is formed towards the interference wave signal in 135 degrees. The output SIR of 28.26dB is acquired at this time. Drawing 10 is a graph which shows the convergence property of

cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 9 . The number of symbols used for study of an arrival signal is [Equation 31]. It is P(M+1) N=10x(6+1) x800=56000 piece.

[0077] Next, the case where five arrival signals exist is considered. DOA of these arrival signals is [0 degree, 40 degrees, 55 degrees, 220 degrees, 305 degrees], considers as the request wave signal which had asked for one, and has the -6.02dB input SIR by making other four into an interference wave signal. A directivity response pattern is shown in drawing 11 thru/or drawing 15 . A drawing corresponds to the situation that the request wave signal has come from 0 degree, 40 degrees, 55 degrees, 220 degrees, and 305 degrees, respectively, and outputs SIR are 9.09dB - 1.41dB, 2.67dB, 20.03dB, and 10.28dB, respectively. Drawing 12 and drawing 13 show two directivity response patterns about the case of crowded DOA with slight separation of the include angle between 40 degrees and 55 degrees. Both signals serve as main beams and the output SIR of a lower value reduces the engine performance. Here, from drawing 12 and drawing 13 , also in the case of slight in this way include-angle separation, the technique of an ESUPA antenna is applied, and if the array antenna equipment 100 controlled accommodative is used, cross protection will be decreased, about 4.60dB reaches respectively SIR gain (namely, SIR difference of an output and an input), and it can improve by 8.69dB. These patterns of drawing 11 thru/or drawing 15 are acquired after iteration of N= 1000. The number of symbols in a study sequence is the sum total.(7x104). Drawing 16 is a graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 11 .

[0078] Next, number of occurrence is reduced and adaptive control processing of the arrival signal from five sources of a signal in which it has same DOA and same Input SIR as simulation of the graph shown in drawing 11 is reproduced (N= 100). As drawing 17 shows, a beam is formed toward the include angle of 0 degree for which it asks, and the interference wave signal from other DOA (namely, 40 degrees, 55 degrees, 220 degrees, and 305 degrees) is oppressed. Thus, even if it is small number of occurrence, the output SIR of 6.58dB is established still more. Drawing 18 is a graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 17 .

[0079] Finally, the technique of an ESUPA antenna is applied and the statistical engine performance of the output SIR of the array antenna equipment 100 controlled accommodative is considered. Drawing 19 (at the time of N= 40) and drawing 20 (at the time of N= 1000) show the probability Pr (Z>=z) for the output SIR expressed with Z to exceed the real number z to which the abscissa was given. On the occasion of the count in connection with these drawings, the signal for which it asked should come from the include angle of 0 degree, and DOA of an interference wave signal has set it up so that uniformly at random in 0 degree thru/or 359 degrees. All of 1000-set DOA are used in these statistics. As for the curve, the case of the Q= 1 number of interference wave signals, 2, and 3 and 4 is drawn. As an example about how these curves are interpreted, drawing 20 connotes that this ecad antenna can supply the output SIR (if it puts in another way 26.02dB SIR gain) of at least 20dB by 80% of probability in the case of Q= 4. When drawing 19 is compared with drawing 20 , it turns out that more number of occurrence increases the output SIR of the array antenna equipment 100 of this operation gestalt.

[0080] The good solution method has been acquired in the semantics that our adaptive control algorithm explained above has a large cross correlation function between an antenna output and a study sequence signal. As the simulation of an example showed, in the case of the array antenna equipment 100 to which the technique of an ESUPA antenna was applied, the improvement of SIR by the proposed adaptive control algorithm can be received in some practical situations. That is, it is shown that seven array antenna equipments 100 can supply about 26dB SIR gain by 80% of probability at least. Development of the algorithm of the adaptive control processing concerning this invention can be adapted for the terminal of a wireless mobile etc., and makes the technique of the low ESUPA antenna of complexity the applicable thing.

[0081]
[Effect of the Invention] According to the control unit of the array antenna applied to this invention as explained in full detail above Only a predetermined shift amount is made to precess

the reactance value of each variable reactive element one by one in the control unit of the ESUPA antenna of the conventional technique. So that the dip vector of the predetermined performance-index value over each reactance value may be calculated and the performance-index value concerned may serve as max or min based on the calculated dip vector The reactance value of each variable reactive element for turning the main beam of the above-mentioned array antenna in the direction of a request wave, and turning null in the direction of an interference wave is calculated and set up. Therefore, as compared with the conventional example using Hamiltonian **, even if whenever [arrival angle / of a request wave] is strange, adaptive control can be carried out so that the main beam may be turned to a request wave and null may be turned to an interference wave. Especially, in the conventional example using Hamiltonian **, although null cannot be turned to an interference wave, in this invention, it has the characteristic effectiveness that null can be turned to an interference wave.

[0082] Wearing is easy to a notebook computer or electronic equipment like PDA as an antenna for mobile telecom terminals, and when the main beam is scanned in every direction of the level surface, all the variable reactive elements non-supplied electric power function effectively as the wave director or a reflector, and control of the directional characteristics over an incoming wave and two or more interference waves is also very suitable for the control unit of the array antenna concerned.

[Translation done.]

* NOTICES *

JPO and INPIT are not responsible for any
damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

TECHNICAL FIELD

[Field of the Invention] This invention relates to the control unit and the control approach of the array antenna to which electronics control wave director array antenna equipment (it is called ESUPA antenna below Electronically Steerable Passive Array Radiator (ESPAR) Antenna;.) directional characteristics can be changed especially accommodative about the control unit and the control approach of the array antenna to which the directional characteristics of the array antenna equipment which consists of two or more antenna elements can be changed.

[Translation done.]

* NOTICES *

JPO and INPIT are not responsible for any
damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

PRIOR ART

[Description of the Prior Art] The ESUPA antenna of the conventional technique for example "The conventional technical reference 1 T.Ohira et al. and "Electronically steerable passive array radiator antennas for low-cost analog adaptive beamforming and "2000 IEEE International Conference It is proposed in on PhasedArray System & Technology pp.101-104, Dana point, California, May 21-25, and the patent application of 2000" and Japanese Patent Application No. No. 194487 [11 to]. This ESUPA antenna can change the directional characteristics of the above-mentioned array antenna by having the array antenna which consists of the radiating element by which electric power is supplied to a radio signal, at least one parasitic element by which only predetermined spacing is left and prepared from this radiating element, and electric power is not supplied to a radio signal, and the variable reactive element connected to this parasitic element, and changing the reactance value of the above-mentioned variable reactive element.
[0003] As an approach for controlling the above-mentioned ESUPA antenna, in order to optimize the reactance value of each variable reactive element in the patent application of an application for patent No. 198560 [2000 to], a reactance value which makes antenna gain of the specified azimuth max is calculated by having used Hamiltonian **.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] According to the control unit of the array antenna applied to this
invention as explained in full detail above Only a predetermined shift amount is made to precess
the reactance value of each variable reactive element one by one in the control unit of the
ESUPA antenna of the conventional technique. So that the dip vector of the predetermined
performance-index value over each reactance value may be calculated and the performance-
index value concerned may serve as max or min based on the calculated dip vector The
reactance value of each variable reactive element for turning the main beam of the above-
mentioned array antenna in the direction of a request wave, and turning null in the direction of
an interference wave is calculated and set up. Therefore, as compared with the conventional
example using Hamiltonian **, even if whenever [arrival angle / of a request wave] is strange,
adaptive control can be carried out so that the main beam may be turned to a request wave and
null may be turned to an interference wave. Especially, in the conventional example using
Hamiltonian **, although null cannot be turned to an interference wave, in this invention, it has
the characteristic effectiveness that null can be turned to an interference wave.
[0082] Wearing is easy to a notebook computer or electronic equipment like PDA as an antenna
for mobile telecom terminals, and when the main beam is scanned in every direction of the level
surface, all the variable reactive elements non-supplied electric power function effectively as the
wave director or a reflector, and control of the directional characteristics over an incoming wave
and two or more interference waves is also very suitable for the control unit of the array
antenna concerned.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] However, in this conventional example, whenever
[arrival angle / of an input signal] needed to be given beforehand, and there was a trouble that
it was not practical and null could not be turned to an interference wave.
[0005] It is in the object of this invention offering the control unit and the control approach of an
array antenna which can carry out adaptive control so that the above trouble is solved, it is not
necessary in control of an ESUPA antenna to give whenever [arrival angle / of an input signal]
beforehand, and the main beam may be turned to a request wave and null may be turned to an
interference wave.

[Translation done.]

MEANS

[Means for Solving the Problem] A radiating element for the control unit of the array antenna
concerning this invention to receive a radio signal, Two or more parasitic elements in which only
predetermined spacing was left and prepared from the above-mentioned radiating element, By
having two or more variable reactive elements connected to two or more above-mentioned
parasitic elements, respectively, and changing the reactance value of each above-mentioned
variable reactive element In the control unit of the array antenna to which two or more above-
mentioned variable reactive elements are operated as the wave director or a reflector,
respectively, and the directional characteristics of an array antenna are changed Only a
predetermined shift amount is made to precess the reactance value of each above-mentioned
variable reactive element one by one. So that the dip vector of the predetermined performance-
index value over each reactance value may be calculated and the performance-index value
concerned may serve as max or min based on the calculated dip vector It is characterized by
having the control means which calculates and sets up the reactance value of each variable
reactive element for turning the main beam of the above-mentioned array antenna in the
direction of a request wave, and turning null in the direction of an interference wave.
[0007] In the control unit of the above-mentioned array antenna moreover, the above-mentioned
control means An input signal when the above-mentioned array antenna receives the study
sequence signal preferably included in the radio signal transmitted from a phase hand's
transmitter, It is the same as that of the above-mentioned study sequence signal, and the
above-mentioned performance-index value is calculated based on the study sequence signal
generated in the control means concerned. It controls so that the performance-index value
concerned serves as max, and the above-mentioned performance index is characterized by being
a cross correlation function between the study sequence signals by which generating was carried
out [above-mentioned] with the above-mentioned input signal.
[0008] In the control unit of the above-mentioned array antenna furthermore, the above-
mentioned control means An input signal when the above-mentioned array antenna receives the
study sequence signal preferably included in the radio signal transmitted from a phase hand's
transmitter, It is the same as that of the above-mentioned study sequence signal, and the
above-mentioned performance-index value is calculated based on the study sequence signal
generated in the control means concerned. It controls so that the performance-index value
concerned serves as min, and the above-mentioned performance index is characterized by being
a square error between the study sequence signals by which generating was carried out [above-
mentioned] with the above-mentioned input signal.
[0009] Furthermore, in the control unit of the above-mentioned array antenna, the above-
mentioned control means calculates the above-mentioned performance-index value based on an
input signal when the above-mentioned array antenna receives preferably the radio signal
transmitted from a phase hand's transmitter, it controls it so that the performance-index value
concerned serves as min, and it is characterized by the above-mentioned performance index
being a function which serves as min when the envelope of the above-mentioned input signal
serves as constant value.
[0010] Moreover, the control approach of the array antenna concerning this invention The

radiating element for receiving a radio signal, and two or more parasitic elements in which only predetermined spacing was left and prepared from the above-mentioned radiating element, By having two or more variable reactive elements connected to two or more above-mentioned parasitic elements, respectively, and changing the reactance value of each above-mentioned variable reactive element In the control approach of the array antenna to which two or more above-mentioned variable reactive elements are operated as the wave director or a reflector, respectively, and the directional characteristics of an array antenna are changed Only a predetermined shift amount is made to precess the reactance value of each above-mentioned variable reactive element one by one. So that the dip vector of the predetermined performance-index value over each reactance value may be calculated and the performance-index value concerned may serve as max or min based on the calculated dip vector It is characterized by including the step which calculates and sets up the reactance value of each variable reactive element for turning the main beam of the above-mentioned array antenna in the direction of a request wave, and turning null in the direction of an interference wave.
[0011]
[Embodiment of the Invention] Hereafter, the operation gestalt which starts this invention with reference to a drawing is explained.
[0012] Drawing 1 is the block diagram showing the configuration of the control device of the array antenna which is an operation gestalt concerning this invention. The control unit of the array antenna of this operation gestalt is equipped with the array antenna equipment 100 which consisted of ESUPA antennas of the conventional technique which is equipped with one feed antenna element A0, six variable reactive elements A1 non-supplied electric power, or A6, and becomes, the adaptive control mold controller 40, and the study sequence signal generator 41 as shown in drawing 1 .
[0013] The adaptive control mold controller 40 consists of digital computers, such as a computer, here. Input-signal [before starting radiocommunication by the demodulator 42, when the feed antenna element A0 of the above-mentioned array antenna equipment 100 receives the study sequence signal included in the radio signal transmitted from a phase hand's transmitter] y (t), It is based on study sequence signal r (t) which is the same as that of the above-mentioned study sequence signal, and was generated with the study sequence signal generator 41. By performing adaptive control processing of drawing 8 It is characterized by calculating and setting up each variable reactive element A1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance value xm (m= 1, 2, --, 6) of A6. Specifically the adaptive control mold controller 40 Only predetermined shift-amount delta xm is made to precess each variable reactive element A1 thru/or the reactance value xm (m= 1, 2, --, 6) of A6 one by one. The predetermined performance index over each reactance value (with this operation gestalt) Calculate the dip vector of the value of cross-correlation-function rhon between study sequence signal r (t) by which generating was carried out [above-mentioned] with input-signal y (t) expressed with several 23, and so that the performance-index value concerned may serve as max based on the calculated dip vector Each variable reactive element A1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in the direction of an interference wave thru/or the reactance value xm (m= 1, 2, --, 6) of A6 are calculated and set up.
[0014] In drawing 1 , the radio signal transmitted from a phase hand's transmitter is received by array antenna equipment 100, and the signal outputted from the feed antenna element A0 is transmitted to the adaptive control mold controller 40 and a demodulator 42 as input-signal y (t) through the RF receive section 35 which processes frequency conversion to low noise magnification, an intermediate frequency, or a berth band etc. After carrying out adaptive control of the above-mentioned adaptive control mold controller 40 so that above-mentioned adaptive control processing may be performed, and the main beam of the control device 100 of an array antenna may be turned in the direction of a request wave and null may be turned in the direction of an interference wave, radiocommunication by the demodulator 42 is started. Here, to received input-signal y (t), a demodulator 42 performs processing of a recovery etc., and acquires and

outputs a recovery signal.

[0015] First, the configuration of the array antenna equipment 100 which consisted of ESUPA antennas with reference to drawing 2 thru/or drawing 5 is explained. As shown in drawing 2 , in array antenna equipment 100 The feed antenna element A0, It insulates from a conductor 11 electrically. the conductor with which six variable reactive elements A1 non-supplied electric power thru/or A6 have a size large enough to each nothing feed variable reactive element A0 thru/or the die length lo and lm (m= 1, 2, --, 6) of A6, respectively -- the touch-down which becomes with a plate -- And it is prepared so that the variable reactive element A1 non-supplied electric power thru/or A6 may be mutually arranged at intervals of the 60 same degrees in the location of the circular configuration of radius d=lambda / 4 (however, lambda wavelength) centering on the feed antenna element A0. Here, array antenna equipment 100 is a reversible circuit, and when using as a transmitting antenna, while electric power is supplied to a radio signal by only the feed antenna element A0, when using as a receiving antenna, the radio signal from a phase hand's transmitter is received by the feed antenna element A0 as input-signal y (t).

[0016] drawing 3 -- setting -- the feed antenna element A0 -- for example, the die length lo of lambda/4 of predetermined longitudinal directions -- having -- touch-down -- it has the cylindrical shape-like radiating element 6 insulated electrically [a conductor 11], and the central conductor 21 of the coaxial cable 20 which transmits the radio signal received by the radiating element 6 is connected to the end of a radiating element 6 -- having -- the outer conductor 22 -- touch-down -- it connects with a conductor 11. This transmits further the radio signal received by the radiating element 6 to the adaptive control mold controller 40 and a demodulator 42 through the RF receive section 35 through a coaxial cable 20.

[0017] drawing 4 -- setting -- each nothing feed variable reactive element A1 thru/or A6 -- respectively -- for example, the die length lm (m= 1, 2, --, 6) of lambda/4 of predetermined longitudinal directions -- having -- touch-down -- it has the parasitic element 7 of the shape of a cylindrical shape insulated electrically [a conductor 11], and the variable reactive element 23 which has the reactance value xm (m= 1, 2, --, 6), and it has the same structure and is constituted. here -- the end of a parasitic element 7 -- a variable reactive element 23 -- minding -- touch-down -- it is grounded in RF to a conductor 11. For example, when the die length of the longitudinal direction of a radiating element 6 and a parasitic element 7 assumes substantially that it is the same (for example, when a variable reactive element 23 has inductance nature (L nature)), a variable reactive element 23 serves as an extension coil, and the variable reactive element A1 non-supplied electric power thru/or the electric merit of A6 become long as compared with the feed antenna element A0, and it works as a reflector. On the other hand, when a variable reactive element 23 has capacitance nature (C nature), a variable reactive element 23 serves as a loading condenser, and the variable reactive element A1 non-supplied electric power thru/or the electric merit of A6 become short as compared with the feed antenna element A0, and it works as the wave director. In actual application, Reactance xm can be restrained in fixed range, such as until -300ohm to 300ohm.

[0018] Drawing 5 is the sectional view showing the detailed configuration of the array antenna equipment 100 of drawing 1 , and variable-capacitance-diode D is used for it as a variable reactive element 23 with the desirable operation gestalt of drawing 5 .

[0019] drawing 5 -- setting -- for example, the top face of the dielectric substrates 10, such as a polycarbonate, -- touch-down -- a conductor 11 forms -- having -- a radiating element 6 -- touch-down -- insulating from a conductor 11 electrically, the dielectric substrate 10 is penetrated in the thickness direction, and it is supported. moreover, the parasitic element 7 -- touch-down -- insulating from a conductor 11 electrically, the dielectric substrate 10 is penetrated in the thickness direction, and it is supported. the through hole which comes to carry out restoration formation by the end of a parasitic element 7 penetrating variable-capacitance-diode D and the dielectric substrate 10 in the thickness direction here -- a conductor 12 -- minding -- touch-down -- while being grounded by the conductor 11 in RF, it connects with Terminal T through Resistance R. moreover, the through hole which comes to carry out restoration formation by Terminal T penetrating the capacitor C for a high frequency bypass, and

the dielectric substrate 10 in the thickness direction —— a conductor 13 —— minding —— touch-down —— it is grounded by the conductor 11 in high frequency.

[0020] Adjustable electrical-potential-difference DC power supply 30 by which armature-voltage control is carried out by the adaptive control mold controller 40 are connected to Terminal T, and the electrostatic-capacity value in variable-capacitance-diode D is changed to it by changing by this the reverse bias electrical potential difference impressed to variable-capacitance-diode D. The electric merit of the variable reactive element A1 equipped with the parasitic element 7 non-supplied electric power can be changed by this as compared with the feed antenna element A0, and the flat-surface directivity property of the array antenna equipment 100 concerned can be changed. Furthermore, the variable reactive element A2 equipped with other parasitic elements 7 non-supplied electric power thru/or A6 are constituted similarly, and has the same operation.

[0021] The array antenna equipment 100 constituted as mentioned above is called an ESUPA antenna. With this operation gestalt, the control unit and the control approach for controlling the flat-surface directivity property of the whole array antenna equipment 100 accommodative are offered by changing further the reactance value of the variable reactive element 23 connected to each nothing feed variable reactive element A1 thru/or A6 in the array antenna equipment 100 of <u>drawing 1</u> .

[0022] The reactance value signal which is an output signal from the adaptive control mold controller 40 for the array antenna equipment 100 which consisted of ESUPA antennas is simply formulized as a function of these six reactances. [Equation 1] which has the reactance value of each variable reactive element 23 as a component with this operation gestalt Since a reactance vector, and a call and the above-mentioned reactance vector are adjustable, the vector expressed with $x**[x1, x2, ——, x6]$ T is used for formation of the directivity response pattern of array antenna equipment 100.

[0023] It sets in this operation gestalt and is [Equation 2] about signal vector s (t). Defining by $s(t) =[s0 (t), s1 (t), ——, s6 (t)]$ T, Component sm (t) is a RF signal received by the m-th antenna element (m= 0, 1, ——, 6) Am (namely, a feed antenna element or the reactive element non-supplied electric power) of array antenna equipment 100, and superscript T expresses transposition of a vector or a matrix. next, input-signal y (t) which is RF output signal of the single port of array antenna equipment 100 —— (—— the following principle explanation —— explanation —— the RF signal (RF signal) in the preceding paragraph of the RF receive section 35 is said for convenience.) —— it is given by the degree type.

[Equation 3] $y(t)=iTs(t)$

It is here and is [Equation 4]. $i=[i0, i1, i2, ——, i6]$ T is a vector which has RF current which appears on the m-th antenna element Am as a component im.

[0024] According to the electromagnetic-field analysis of array antenna equipment 100, RF current phasor i is formulized like a degree type.

[Equation 5] $i=(I+jYX)-1y0$[0025] Here, I is the unit matrix of x (6+1) (6+1), and is a diagonal matrix [several 6]. $X=diag [x0, x1, x2, ——, x6]$

It is called ** and a reactance matrix. The input impedance x0 of the adaptive control mold controller 40 and a demodulator 42 is fixed, and it is assumed to be x0=0 with this operation gestalt, without losing generality. Furthermore, at several 5, a vector y0 is [Equation 7]. It defines by $y=[0] [y00, y10, y20, ——, y60]$ T, and is [Equation 8]. $Y=[ykl] (6+1) x (6+1)$ shall be the admittance matrix of x (6+1) (6+1). Here, Component ykl expresses the mutual admittance between antenna elements Ak and aluminum (0<=k, l<=6).

[0026] (6+1) In the case of the array antenna equipment 100 of a component, a vector y0 and admittance-matrix Y are determined only of six components of mutual admittance. This is explained below.

[0027] By the well-known reciprocity theorem, a degree type is realized like the array antenna equipment of an ordinary type.

[Equation 9] $ykl=ylk$ [0028] Furthermore, the patrol symmetric property of the antenna element Am of array antenna equipment 100 connotes the degree type.

[0029]

[Equation 10] y11=y22=y33=y44=y55=y66 — [Equation 11] y01=y02=y03=y04=y05=y06 —
[Equation 12] y12=y23=y34=y45=y56=y61 — [Equation 13] y13=y24=y35=y46=y51=y62 —
[Equation 14] y14=y25=y36[0030] Nine above thru/or several 14 mean that several 8 admittance matrix is determined only by six components y00, y10, y11, y21, y31, and y41 of mutual admittance. As for this, therefore, the value of six components is fixed depending on the physical structure of antennas, such as a radius of an antenna element Am, space spacing, and die length. Old explanation is summarized and admittance-matrix Y in several 5 is written like a degree type.

[0031]
[Equation 15]

$$Y = \begin{bmatrix} y_{00} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} & y_{10} \\ y_{10} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} \\ y_{10} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} & y_{31} \\ y_{10} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} & y_{41} \\ y_{10} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} & y_{31} \\ y_{10} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} & y_{21} \\ y_{10} & y_{21} & y_{31} & y_{41} & y_{31} & y_{21} & y_{11} \end{bmatrix}$$

[0032] Similarly, several 7 can be rewritten as follows.
[Equation 16] Y=[y00, y10, y10, —, y10] T [0033] That signal vector s (t) in several 3 received by the antenna element of array antenna equipment 100 cannot measure is the point which should be emphasized. This differs from the usual ecad array antenna with which the signal vector received on an antenna element is observed. In the case of array antenna equipment 100, it is measurable in input-signal y (t) which is a single-port output, and is used as feedback by which only this controls the reactance vector x of a-one number. Though still more regrettable, as shown in several 5, input-signal y (t) which is a single-port output is the high order nonlinear function of the reactance vector x, the operation of an inverse matrix is included and this makes generation of an analytical expression of adaptability ability difficult. Moreover, it should be warned that current phasor i in several 5 is also equivalent to the weighting-factor vector of the usual ecad array. Each component of join [together / unlike the weighting-factor vector of the usual ecad array / independently and mutually] of current phasor i is clear from several 5. The above-mentioned argument connotes that most control algorithms of the usual ecad array antenna cannot be directly applied to the array antenna equipment 100 to which the technique of an ESUPA antenna was applied. Therefore, it is desirable to propose the algorithm for adaptive control for an ESUPA antenna especially.
[0034] Subsequently, in order to make the array antenna equipment 100 of this operation gestalt into an ecad, the model of the signal received is proposed. Before advancing a study, the steering vector of array antenna equipment 100 is given. The array antenna equipment 100 of a component as shown in drawing 6 (6+1) is considered.
[0035] About the m-th antenna element Am, it is an include angle [several 17] to the shaft of arbitration.
phim=2pi (m-1) / 6 (m= 1, 2, —, 6),
It comes out and arranges. The case of m= 2 is illustrated in drawing 6 . It comes from whenever [arrival angle / of an include angle theta] (DOA) by using the shaft of the above-mentioned arbitration as a reference axis, and when the wave front received on array antenna equipment 100 is observed, spatial delay of d-cos (theta-phim) exists between the signals which the pair of the m-th reactive element Am non-supplied electric power and the 0th feed antenna element A0 receives. This spatial delay is changed into the degree difference of electric target angle defined by d-cos (2 pi/lambda) (theta-phim) with wavelength lambda. Therefore, the steering vector of the array antenna equipment 100 in DOA of an include angle theta is defined by the degree type when radii are d=lambda/4.
[0036]
[Equation 18]

$$a(\theta) = \begin{bmatrix} 1 \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_1)\} \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_2)\} \\ \vdots \\ \exp\{j\frac{\pi}{2}\cos(\theta-\phi_6)\} \end{bmatrix}$$

[0037] The above-mentioned case of being simple can be extended when more general. DOA assumes that there is a total of Q+a source of a signal which transmits the arrival input signal uq (t) which is thetaq (q= 0, 1, ――, Q). m= 0, and (1, ――, 6) express the signal received by the m-th antenna element Am of an antenna, and they presuppose that it is s (t) the column vector which has sm (t) for the m-th component. [sm (t) and] Signal sm (t) is the superposition of the signal from Q+1 source of a signal.

[0038]
[Equation 19]

$$s_m(t) = \sum_{q=0}^{Q} a_m(\theta_q)u_q(t), \quad (m=0,1,\cdots,6)$$

[0039] Here, am (m= 0, 1, 2, ――, 6) (thetaq) is the m-th component of several 18 which has thetaq instead of theta. At this time, column vector s (t) which appears in an antenna element Am can be expressed like a degree type.

[0040]
[Equation 20]

$$s(t) = \sum_{q=0}^{Q} a(\theta_q)u_q(t)$$

[0041] It is here and is [Equation 21]. a(thetaq) **[a0 (thetaq), a1 (thetaq), a2 (thetaq), ――, a6 (thetaq)] T is the steering vector defined in several 18 which has thetaq instead of theta. From several 3, input-signal y (t) which is the output signal of array antenna equipment 100 can be written like a degree type.

[0042]
[Equation 22]

$$y(t) = i^T s(t) = \sum_{q=0}^{Q} i^T a(\theta_q)u_q(t)$$

[0043] current phasor i ―― and ―― therefore, input-signal y (t) is the function of the reactance vector x of several 1.

[0044] Next, the adaptive control processing of array antenna equipment 100 based on inclination is explained. It is assumed that study sequence signal r (t) currently used by this adaptive control processing is known by the both sides of the transmitter and receiver of a phase hand. A little convention of a notation is changed and henceforth writes the equivalence low pass signal of RF output of array antenna equipment 100 by input-signal y (t) with this operation gestalt.

[0045] The performance index generally used with the conventional maximum grade algorithm is a 2nd [an average of] power error. It is common knowledge that a cross correlation function expresses approximation nature to this error expressing the difference of two signals. Instead of an error, the cross correlation function is adopted by our adaptive control processing the 2nd [an average of] power. Our object in here is to discover the reactance vector x of several 1 to which the cross correlation function between input-signal y (t) which is the output of an antenna, and study sequence signal r (t) becomes as large as possible.

[0046] y (n) and r (n) are assumed to be the P-dimensional vectors which are the discrete time amount sample of input-signal y (t) and study sequence signal r (t) respectively. The cross correlation function between input-signal y (n) in time of day n and study sequence signal r (n) is

defined like a degree type.
[0047]
[Equation 23]

$$\rho_n = \frac{\left|y(n)r(n)^H\right|}{\sqrt{y(n)y(n)^H}\,\sqrt{r(n)r(n)^H}}$$

[0048] Here, superscript H expresses the transposition which takes a complex conjugate. Thereby, a gradient vector is defined like a degree type.
[0049]
[Equation 24]

$$\nabla\rho_n \equiv \frac{\partial\rho_n}{\partial x} \equiv \begin{bmatrix} \dfrac{\partial\rho_n}{\partial x_1} \\ \dfrac{\partial\rho_n}{\partial x_2} \\ \vdots \\ \dfrac{\partial\rho_n}{\partial x_6} \end{bmatrix}$$

[0050] Here, **rhon/**x express the derivative about the reactance vector x.
[0051] The following procedures are used in order to discover the good reactance vector x which enlarges a cross correlation function as much as possible by the maximum grade method.
(i) First, time of day n (namely, n-th iteration) is set as 1, and it starts with the initial value x of the reactance vector chosen as arbitration (1). Typically, when an early directivity response pattern is omnidirectional, the initial value x of a reactance vector (1) is set up equally to the zero vector.
(ii) Subsequently gradient vector **rhon in time of day n (namely, n-th iteration) is calculated by using this initial value or current estimate.
(iii) The following estimate in a reactance vector is calculated by changing initial value or current estimate in the same direction as the direction of a gradient vector.
(iv) It returns to a step (ii) and processing is repeated.
[0052] The following steps are performed with reference to drawing 8 showing flow drawing of the adaptive control processing proposed in detail. Before the demodulator 42 of drawing 1 starts radiocommunication, this adaptive control processing is performed when having received the radio signal including the study sequence signal from a phase hand's transmitter.
[0053] In drawing 8 , first, in step S1, it is set as n= 1 and the reactance vector x (n) of several 1 in time of day n (n-th iteration) is set as the initial value x of the reactance vector chosen as arbitration (1). Subsequently, in step S2, before starting the inner loop formation of drawing 8 , it considers as a parameter m= 0 and input-signal y (t) is measured in step S3. And in step S4, cross-correlation-function rhon is calculated using several 23, and the above-mentioned cross-correlation-function rhon is substituted for criteria multiplier (multiplier of non-perturbation) rho [before perturbation] n (0). Furthermore, only 1 increments Parameter m and only delta xm is made to precess the m-th component xm of a reactance vector in step S6 in step S5. And in step S7, input-signal y (t) is measured and cross-correlation-function rhon is calculated in step S8 using several 23. Subsequently, in step S9, derivative **rhon/**xi which shows the inclination about the reactance vector x of a cross correlation function is calculated by rhon-rhon (0). Furthermore, in step S10, the m-th component xm of a reactance vector made to precess at step S6 is returned. and the step S11 -- setting -- Parameter m -- several [the variable reactive element A1 non-supplied electric power thru/or / of A6] -- while judging whether it is smaller than M= 6 and returning to step S5 by the inner loop formation at the time of m<M, it progresses to step S12 at the time of m>=M.
[0054] In step S12, the updating value x (n+1) of the reactance vector x in time of day n+1 is calculated as follows using recursive relation according to an above-mentioned maximum grade method.

[Equation 25] x(n+1) = x (n) +mu**rhon [0055] Here, mu is a forward constant which controls a convergence rate, for example, is set as mu= 150. Subsequently, in step S13, only 1 increments n, and in step S14, while n judges whether the number of occurrence N determined beforehand is reached and returns to step S2 by the outside loop formation at the time of n<=N, the adaptive control processing concerned is ended at the time of n>N. Adaptive control can be carried out so that it can be made to converge so that a performance-index value may be made into max, the main beam of the control device 100 of an array antenna may be turned to a request wave even if whenever [arrival angle / of a request wave] is strange, and null may be turned to an interference wave by the above adaptive control processing.

[0056] It is intuitively appropriate to become the reactance vector x good after all in the semantics that the continuous amendment of the reactance vector x performed to the positive direction of a gradient vector has a large cross correlation function.

[0057] There are some difficult cases where it is, on the occasion of count of gradient vector **rhon of several 24. As mentioned above, this originates in the data that expressing a gradient vector analytically as a function of the reactance vector x cannot observe the signal vector received in the feed antenna element A0 of (b) array antenna equipment 100 which is not easy (several 3 and several 5 reference) and the parasitic antenna component A1 thru/or each of A6 by the existence of the operation of an inverse matrix with difficult handling in the expression of (a) input-signal y (t).

[0058] In this operation gestalt, the estimate of gradient vector **rhon of several 24 is drawn by the activity of the approximate value by the difference of the finite of a partial derivative. Especially, partial-derivative **rhon/**xi of the first floor about Reactance xi is approximated to the variation of cross-correlation-function rhon by taking an increment to xm+delta xm in Reactance xm.

[0059]
[Equation 26]

$$\frac{\partial \rho_n}{\partial x_m} \approx \rho_n(x_1, x_2, \cdots, x_m + \Delta x_m, \cdots x_6) - \rho_n(x_1, x_2, \cdots, x_m, \quad \cdots x_6), \quad m = 1, 2, \cdots, 6,$$

[0060] The reactance vector x (n+1) is computed by substituting assessment of this gradient vector for several 26. These steps are repeated from n= 1 to n=N, and the good reactance vector x (N+1) is acquired in the semantics that cross-correlation-function rhoN is large, about sufficiently large N.

[0061] As shown in several 26, from the output of an antenna, only only one component of gradient vector **rhon is computed at once. All the components of the reactance vector x are serially precessed on a target, and one gradient vector is obtained repeatedly [each / of several 25]. Drawing 7 shows the framework structure of used study sequence signal r (t). N) is 1, 2, --, a pseudo-random signal that consists of 1 and -1, respectively. data block r (i) -- (-- i= -- each of data block r (1), r (2), --, r (N) In the loop formation from step S5 of drawing 8 to step S11, in order to calculate M+1 component (it sets in this operation gestalt and is M= 6) of the gradient vector of a correlation coefficient, are repeated by a unit of M+1 time. That is, M+1 transmission of data block r (i) is once needed for a repeat. Here, data block [M+1 time of] r (i) is used in order to measure input-signal y (t) and input-signal [at the time of M perturbation] y (t) at the time of one un-precessing. In this case, if number [of each data block] of symbols r (i) is set to P, since it will repeat calculating the estimate of a reactance from the above-mentioned gradient vector N times, study sequence signal r (t) consists of a symbol of a Px(M+1) xN individual.

[0062] As explained above, according to the operation gestalt concerning this invention, the adaptive control mold controller 40 Input-signal [before starting radiocommunication by the demodulator 42, when the feed antenna element A0 of the above-mentioned array antenna equipment 100 receives the study sequence signal included in the radio signal transmitted from a phase hand's transmitter] y (t), It is based on study sequence signal r (t) which is the same as that of the above-mentioned study sequence signal, and was generated with the study sequence signal generator 41. Each variable reactive element A1 for turning the main beam of the above-mentioned array antenna equipment 100 in the direction of a request wave, and turning null in

the direction of an interference wave thru/or the reactance value xm (m= 1, 2, —, 6) of A6 are calculated and set up by performing adaptive control processing of <u>drawing 8</u> . Therefore, as compared with the conventional example which used Hamiltonian **, even if whenever [arrival angle / of a request wave] is strange, adaptive control of the control unit or the control approach of an array antenna concerning this operation gestalt can be carried out so that the main beam may be turned to a request wave and null may be turned to an interference wave.

[0063] In the operation gestalt beyond a <modification>, although six variable reactive elements A1 non-supplied electric power thru/or A6 are used, if there are the two or more [at least] numbers, they can control the directional characteristics of the array antenna equipment concerned electronically. Instead of it, you may have many variable reactive elements non-supplied electric power rather than six pieces. Moreover, the variable reactive element A1 non-supplied electric power thru/or the arrangement configuration of A6 were not limited to the above-mentioned operation gestalt, either, but only a predetermined distance has separated it from the feed antenna element A0. That is, each nothing feed variable reactive element A1 thru/or the spacing d to A6 may not be fixed.

[0064] Furthermore, a variable reactive element 23 is not limited to variable-capacitance-diode D, but should just be a controllable component about a reactance value. Since variable-capacitance-diode D is generally a capacitive circuit element, a reactance value always turns into a negative value. In addition, in the numerical example of a table 1, zero and a forward value are used as an impedance Z. By being very good in the value of the range to a negative value from forward, and for that inserting the inductor of immobilization for example, in variable-capacitance-diode D at a serial, or lengthening the die length of a parasitic element 7 more, it can go over the reactance value of the above-mentioned variable reactive element 23 by the negative value from forward, and it can change a reactance value.

[0065] In this above operation gestalt, although cross-correlation-function rhon was used as a performance index of a maximum grade method, this invention may use not only this but other functions. As the example, square error criteria and constant envelope criteria are explained. The performance index of square error criteria is expressed with a degree type.

[0066]

[Equation 27] $J=E[|r'(t)-y'(t)|2]$

[0067] Here, |-| expresses the absolute value of complex and E [-] expresses an ensemble average. Moreover, input-signal y (t) and study sequence signal r (t) are normalized like the degree type.

[0068]

[Equation 28] $y'(t) =y(t) y[/] (t) |$ — [Equation 29] $r'(t) =r(t)/|r (t) |$ [0069] When using the performance index of square error criteria, adaptive control of the adaptive control mold controller 40 is carried out so that the performance-index value J may serve as min.

[0070] Moreover, the performance index of the constant envelope criteria of having used the CMA algorithm is expressed with a degree type.

[0071]

[Equation 30] $J=E[||y'(t)|2-1|2]$

[0072] Input-signal y (t) is normalized by the same y' (t) as several 28 also here. Although study sequence signal r (t) is unnecessary at this time, it can be used only by system by which the envelope of an input signal serves as constant value. It is a system which specifically adopts modulation techniques, such as FM, BPSK, and QPSK. The adaptive control mold controller 40 calculates the above-mentioned performance-index value based on input-signal [when array antenna equipment 40 receives the radio signal transmitted from a phase hand's transmitter] y (t), when the performance index of constant envelope criteria is used, it controls it so that the performance-index value concerned serves as min, and the above-mentioned performance index is a function used as min, when the envelope of the above-mentioned input signal serves as constant value.

[0073] each data block r (i) which constitutes study sequence signal r (t) in the above operation gestalt — (— i= — 1, 2, —, N) — several symbols — although it was the pseudo-random signal which is P= 10, you may be the signal of other numbers of symbols. Moreover, adaptive control

processing using a study sequence may be performed to the communicative beginning, or you may carry out for every time period of a certain.

[Translation done.]

* NOTICES *

JPO and INPIT are not responsible for any
damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

EXAMPLE

[Example] Furthermore, the simulation using the control unit of the array antenna of this operation gestalt and its result are explained.
[0075] It is possible to make it difficult to describe analytically [the engine performance] existence (several 3 and several 5 reference) of the inverse matrix in the output expression from array antenna equipment 100. Simulation was carried out in order to verify the algorithm and antenna engine performance which were proposed. In our simulation, the array antenna equipment 100 which consisted of ESUPA antennas of a component (6+1) is used. The feed antenna element A0 and the reactive element A1 non-supplied electric power thru/or A6 are lambda/4 merit's monopole components, respectively. us -- all the arrival signals uq (t) -- (-- q= -- the power of 0, 1, --, Q) was chosen so that it might be set to 1. The noise assumed that it was what is not. The number of symbols of the data block for each count of the cross correlation function defined as several 23 was set as P= 10 through all simulation.
[0076] First, the case where two signals exist from a different direction is considered. An input signal pair interference wave power ratio (a signal pair interference wave power ratio is hereafter called SIR.) is 0dB by the assumption whose arrival signal is the power of 1. As after iteration of N= 800 is shown in drawing 9 , a beam is turned to 0 degree of the signal for which it asks, and deeper null is formed towards the interference wave signal in 135 degrees. The output SIR of 28.26dB is acquired at this time. Drawing 10 is a graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 9 . The number of symbols used for study of an arrival signal is [Equation 31]. It is P(M+1) N=10x(6+1) x800=56000 piece.
[0077] Next, the case where five arrival signals exist is considered. DOA of these arrival signals is [0 degree, 40 degrees, 55 degrees, 220 degrees, 305 degrees], considers as the request wave signal which had asked for one, and has the -6.02dB input SIR by making other four into an interference wave signal. A directivity response pattern is shown in drawing 11 thru/or drawing 15 . A drawing corresponds to the situation that the request wave signal has come from 0 degree, 40 degrees, 55 degrees, 220 degrees, and 305 degrees, respectively, and outputs SIR are 9.09dB − 1.41dB, 2.67dB, 20.03dB, and 10.28dB, respectively. Drawing 12 and drawing 13 show two directivity response patterns about the case of crowded DOA with slight separation of the include angle between 40 degrees and 55 degrees. Both signals serve as main beams and the output SIR of a lower value reduces the engine performance. Here, from drawing 12 and drawing 13 , also in the case of slight in this way include-angle separation, the technique of an ESUPA antenna is applied, and if the array antenna equipment 100 controlled accommodative is used, cross protection will be decreased, about 4.60dB reaches respectively SIR gain (namely, SIR difference of an output and an input), and it can improve by 8.69dB. These patterns of drawing 11 thru/or drawing 15 are acquired after iteration of N= 1000. The number of symbols in a study sequence is the sum total (7x104). Drawing 16 is a graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 11 .
[0078] Next, number of occurrence is reduced and adaptive control processing of the arrival signal from five sources of a signal in which it has same DOA and same Input SIR as simulation

of the graph shown in drawing 11 is reproduced (N= 100). As drawing 17 shows, a beam is formed toward the include angle of 0 degree for which it asks, and the interference wave signal from other DOA (namely, 40 degrees, 55 degrees, 220 degrees, and 305 degrees) is oppressed. Thus, even if it is small number of occurrence, the output SIR of 6.58dB is established still more. Drawing 18 is a graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 17 .

[0079] Finally, the technique of an ESUPA antenna is applied and the statistical engine performance of the output SIR of the array antenna equipment 100 controlled accommodative is considered. Drawing 19 (at the time of N= 40) and drawing 20 (at the time of N= 1000) show the probability Pr (Z>=z) for the output SIR expressed with Z to exceed the real number z to which the abscissa was given. On the occasion of the count in connection with these drawings, the signal for which it asked should come from the include angle of 0 degree, and DOA of an interference wave signal has set it up so that uniformly at random in 0 degree thru/or 359 degrees. All of 1000-set DOA are used in these statistics. As for the curve, the case of the Q= 1 number of interference wave signals, 2, and 3 and 4 is drawn. As an example about how these curves are interpreted, drawing 20 connotes that this ecad antenna can supply the output SIR (if it puts in another way 26.02dB SIR gain) of at least 20dB by 80% of probability in the case of Q= 4. When drawing 19 is compared with drawing 20 , it turns out that more number of occurrence increases the output SIR of the array antenna equipment 100 of this operation gestalt.

[0080] The good solution method has been acquired in the semantics that our adaptive control algorithm explained above has a large cross correlation function between an antenna output and a study sequence signal. As the simulation of an example showed, in the case of the array antenna equipment 100 to which the technique of an ESUPA antenna was applied, the improvement of SIR by the proposed adaptive control algorithm can be received in some practical situations. That is, it is shown that seven array antenna equipments 100 can supply about 26dB SIR gain by 80% of probability at least. Development of the algorithm of the adaptive control processing concerning this invention can be adapted for the terminal of a wireless mobile etc., and makes the technique of the low ESUPA antenna of complexity the applicable thing.

[Translation done.]

* NOTICES *

JPO and INPIT are not responsible for any
damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the block diagram showing the configuration of the control device of the array antenna which is an operation gestalt concerning this invention.
[Drawing 2] It is a perspective view showing the configuration of the array antenna equipment 100 of drawing 1 .
[Drawing 3] It is the mimetic diagram showing the configuration of the feed antenna element A0 of drawing 1 .
[Drawing 4] It is the mimetic diagram showing the variable reactive element A1 of drawing 1 non-supplied electric power thru/or the configuration of A6.
[Drawing 5] It is the sectional view showing the detailed configuration of the array antenna equipment 100 of drawing 2 .
[Drawing 6] It is a top view showing the configuration of the array antenna equipment 100 of drawing 1 .
[Drawing 7] It is the sequence diagram showing the configuration of the study sequence signal generated by the study sequence signal generator 41 of drawing 1 .
[Drawing 8] It is the flow chart which shows the adaptive control processing performed by the adaptive control controller 40 of drawing 1 .
[Drawing 9] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is the graph which shows a directivity response pattern in case the number of the sources of a signal is two.
[Drawing 10] It is the graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 9 .
[Drawing 11] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is a level surface directivity response pattern in case the source of a signal makes the direction of 0 degree a request wave signal by five.
[Drawing 12] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is the graph which shows a level surface directivity response pattern in case the source of a signal makes the direction of 40 degree a request wave signal by five.
[Drawing 13] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is the graph which shows a level surface directivity response pattern in case the source of a signal makes the direction of 55 degree a request wave signal by five.
[Drawing 14] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is the graph which shows a level surface directivity response pattern in case the source of a signal makes the direction of 220 degree a request wave signal by five.
[Drawing 15] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is the graph which shows a level surface directivity response pattern in case the source of a signal makes the direction of 305 degree a request wave signal by five.
[Drawing 16] It is the graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 11 .

[Drawing 17] It is as a result of [of the control unit of the array antenna of drawing 1] simulation, and is the graph which shows a level surface directivity response pattern in case the source of a signal makes the direction of 0 degree a request wave signal by five.

[Drawing 18] It is the graph which shows the convergence property of cross-correlation-function rhon to the number of occurrence n when obtaining the directivity response pattern of drawing 17 .

[Drawing 19] It is the graph which shows the probability for the output SIR in case number of occurrence is 40 times to exceed the value of an axis of abscissa with the control unit of the array antenna of drawing 1 .

[Drawing 20] It is the graph which shows the probability for the output SIR in case number of occurrence is 1000 times to exceed the value of an axis of abscissa with the control unit of the array antenna of drawing 1 .

[Description of Notations]

A0 -- Feed antenna element,

A1 thru/or A6 -- Variable reactive element non-supplied electric power,

C -- Capacitor,

D -- Variable capacitance diode

R -- Resistance,

T -- Terminal,

6 -- Radiating element,

7 -- Parasitic element,

10 -- Dielectric substrate,

11 -- touch-down -- a conductor,

12 and 13 -- through hole -- a conductor,

20 -- Coaxial cable for feed,

21 -- Central conductor,

22 -- Outer conductor,

23 -- Variable reactive element

30 -- Adjustable electrical-potential-difference DC power supply,

35 -- RF receive section,

40 -- Adaptive control mold controller,

41 -- Study sequence signal generator,

42 -- Demodulator,

100 -- Array antenna equipment.

[Translation done.]